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ORIGINAL ARTICLES.

I.—The Fundamental Problems of Petrogenesis, or the Origin of the Igneous Rocks.

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(*Concluded from the June Number, p.* 257.)

§ 2. *On the Causes of the Diversity of Igneous Rocks.*

THE second fundamental problem of petrogenesis is the following question:—By what processes have there been derived, from the original magma or magmas, all other magmas known as igneous rocks? It is now almost universally admitted that many igneous rocks are genetically connected and produced from an original magma by differentiation, and that in many cases differentiation may be considered as liquation or separating into secondary magmas. But is differentiation (*Spaltungen*) alone sufficient to explain the formation of all igneous rocks? And by what is a magma stimulated to differentiation? These are two questions which must be elucidated. It must be first of all emphasized that not every magma is subject to differentiation. My standpoint is that the principal factors producing and regulating differentiation are on one side the process of crystallization (differentiation by crystallization, *Krystallisations-differenzierung*), and on the other the chemical composition of the magma and its tendency to the formation of eutectics (magmatic differentiation).

Gravitation is the principal factor during differentiation by crystallization: crystals are distributed according to their specific gravity, the one rising to upper portions of the magma, the other sinking into deeper and being often dissolved and assimilated there. Corrosion-rims on phenocrysts and orbicular concretions in plutonic rocks, well known to every petrographer, are suggestive illustrations of the fact that there exist in the magma vertical movements of the first products of crystallization. By this process leucocratic and melanocratic modifications may be generated, and there can issue from one original magma several different rocks genetically and chemically connected with it. Such a process can take place in a separate isolated magma-basin cooling very slowly.

The tendency to form eutectic mixtures is certainly a powerful factor in differentiation, which, as I have already pointed out,[1] is from

[1] F. Loewinson-Lessing, "Petrographical Notices. 4. Differentiation, Eutectics, and Entropy": Ann. Inst. Polyt. St. Petersbourg, vi, p. 279, 1906.

the standpoint of entropy not only a possible but a necessary regulator of differentiation. Of course differentiation postulated by the tendency towards eutectics can take place only in a magma which is not itself an eutectic mixture but more or less different from it. If granite and gabbro are really eutexia their magmas must consolidate as a whole, they cannot undergo differentiation without an external impulse, and such an influence is given, as will be shown later, by the admixture and assimilation of foreign mineral masses. And wherever a magma exists the composition of which is not eutectic it must undergo differentiation, if only the cooling and solidification process be not too rapid. In the case of a bimineralic magma there will be generated a monomineralic and a eutectic magma; if the original magma be trimineralic, there will issue a trimineralic eutexia, bimineralic and monomineralic rocks. Differentiation in a eutectic magma is possible only if its composition is modified by the assimilation of foreign masses. The question whether a magma can dissolve and assimilate small portions or considerable quantities of the surrounding rocks has been answered by different geologists in different ways, some denying this possibility, others admitting such a process. During recent years the number of those who admit assimilation has notably increased. It is perhaps sufficient to cite only a few names, as it seems to me that the widespread occurrence of xenoliths and the marginal facies of the intrusive bodies in the contact zones are eloquent illustrations of assimilation on a large scale. And is not assimilation a phenomenon, that must be expected even *a priori* in intrusive bodies, for it is difficult to imagine a magmatic basin heating the rocky masses in contact with it for a long period without partly dissolving them?

Harker[1] considers 'marscoite' to be a case of assimilation of granite by a gabbro-magma. Assimilation on a large scale is admitted by Daly, who has applied this conception to explain the formation of andesites from basalts,[2] and to certain granites.[3] And, in a newly published paper, he tries to demonstrate that all the nepheline-syenites and alkaline rocks connected with them are derivates from granites, owing their distinctive characters to the assimilation of limestones.[4] Becke[5] has attributed the richness in lime and magnesia of the Pacific type of lavas to the fact that there have been assimilated great quantities of sediments, and Suess[6] agrees with this supposition. According to

[1] A. Harker, "The Tertiary Igneous Rocks of Skye": Mem. Geol. Surv., 1904. *Natural History of Igneous Rocks*, p. 356. It must be remembered of course that Harker considers such cases as exceptional, and is an adversary of assimilation on a large scale.

[2] R. Daly, "The Origin of Augite Andesite and of related Ultra-basic Rocks.": Jour. Geol., 1908, p. 401.

[3] R. Daly, "Secondary Origin of certain Granites": Amer. Jour. Sci., xx (4), p. 185, 1905.

[4] R. Daly, См. прим. на Стр. 125.

[5] F. Becke, "Die Eruptivgesteine des böhmischen Mittelgebirges u. d. Amerik. Anden. Atlantische u. pazifische Sippe der Eruptivgesteine": T.M.P.M., xxii, p. 209, 1903.

[6] E. Suess, *Das Antlitz der Erde*, iii, ii, 679, 1909.

Klemm[1] the diorite of the Odenwald originated through gabbro assimilating schists. Adams[2] speaks of limestones assimilated in the contact zone by granites, and thinks that amphibolites have been formed by this process. Michel-Levy, and with him Haug,[3] considers the formation of granite as being accompanied by endogene metamorphism and assimilation on a large scale. I can cite also Philipp,[4] Termier,[5] Munteanu-Murgoci,[6] Cohen (on the laccolites of Piatigorsk), Mackie,[7] Sauer,[8] Michel-Lévy,[9] Lacroix,[10] Lemberg,[11] Doelter,[12] Gürich,[13] Högbom,[14] Hugi,[15] Sollas,[16] Grenville Cole,[17] the 'osmatic' theory of Johnston-Lavis, and many other authors cited in my "Studien über die Eruptivgesteine". It is well known that Sederholm[18] considers assimilation as an important factor in the formation of the crystalline schists.

The above citations do not give a full account of all the advocates of assimilation, but they are sufficient to show that many authors have been led to this conception by various data and considerations.

In different cases where a magma has come in contact with surrounding rocks or with another magma assimilation must be an important factor in differentiation. It is difficult to imagine a deep-seated magmatic basin to remain in contact with eruptive or sedimentary masses and not to dissolve a part of them, as fused silicates dissolve a porcelain crucible. Those who deny this process on account of the absence of zones of corrosion or of marginal zones due to admixture,

[1] G. Klemm, "Beobachtungen über die genetischen Beziehungen der Odenwälder Gabbros und Diorite": Notizbl. Ver. Erdkunde Grosh. geol. Landesanstalt Darmstadt (4), xxvii, 1906.

[2] F. Adams, "On the Origin of the Amphibolites of the Laurentian Area of Canada": Jour. Geol., xvii, p. 7, 1909.

[3] E. Haug, *Traité de Géologie*.

[4] H. Philipp, "Vorläufige Mittheilungen über Resorptions- und Injectionserscheinungen im südl. Schwarzwald": Centrbl. Min., 1907, p. 76.

[5] E. Termier, "Sur le granite alcalin du Filfla (Algérie)": C.R., 1902.

[6] Munteanu-Murgoci, *Ueber die Einschlüsse von Granat-Vesuvianfels in dem Serpentin des Paringu-Massivs*, 1901.

[7] Mackie, "On Differences in Chemical Composition between the Central and the Marginal Zones of Granite Veins, with further evidence of exchanges between such veins and contact rocks": Trans. Edinb. Geol. Soc., viii, p. 98, 1901.

[8] A. Sauer, "Ueber petrographische Studien an den Lavabomben aus dem Ries": Jahresh. Ver. vaterl. Nat. Württemb., lvii, 1901.

[9] A. Michel-Lévy, *Mémoire sur le porphyre bleu de l'Esterel*, 1897.

[10] A. Lacroix, *Guide des excursions, Congrès de Paris*, 1900.

[11] J. Lemberg, *Z. d. g. G.*, 1872.

[12] C. Doelter, "Chemische Zusammensetzung u. Genesis der Monzoni-Gesteine": T.M.P.M., 1902, p. 206.

[13] Gürich, "Granit u. Gneiss": Himmel u. Erde, xvii, p. 6, 1905.

[14] A. Högbom, "Pre-Cambrian Geology of Sweden": Bull. Geol. Inst. Upsala, x, 1910.

[15] Hugi, "Vorläufige Mitteilung über Untersuchungen in der nordlichen Gneiszone des zentralen Aarmassivs": Eclogæ Geol. Helvet., ix, No. 4, 1907.

[16] Sollas, Trans. Roy. Ir. Acad., xxx, p. 505, 1894.

[17] Grenville Cole, Sci. Trans. Roy. Dublin Soc. (2), vi, p. 246, 1897. The last two authors are cited after Harker, *Natural History of Igneous Rocks*, p. 338.

[18] J. Sederholm, "Om Granit och Gneiss": Bull. Com. Géol. Finlande, No. 3, 1907.

seem not to admit that foreign mineral masses must be 'assimilated' in the real sense of the word, commingled with the whole magmatic mass on account of the fluidity of the magma and the gases it contains. In an intrusive body of laccolitic type assimilation takes place in the manner of stoping as elucidated by Daly. A third case of assimilation, when parts of the solid crust are melted by rising of the isogeotherms or by hot gases, will be mentioned later.

Let us now consider what happens when assimilation has taken place. The magma becomes more fluid, its composition is modified; if it was at first eutectic it is now no longer so, and differentiation must begin. It has been stated by Brögger[1] and myself[2] that differentiation consists in the separation (*Abspaltung*) of definite compounds of minerals, and not of separate oxides, as has been formerly presumed by Iddings and others. We have no examples of magmas having an abnormal composition; even the effusive rocks, which are not entirely composed of crystallized minerals like the intrusives and whose glassy parts may have, as it seems, an arbitrary composition, repeat in reality only the same types of magma which are represented by intrusive rocks. This is a very important fact, demonstrating, as I have already explained,[3] "that the effusive and intrusive rocks come from one source; the differentiation of their original magmas is performed in the same way, namely, in the liquid state." It is also important in showing that the abyssal magmas have time enough and sufficient liquidity for differentiation to continue until it is completed, and in such a manner that no abnormal residual magmas can be formed. We may therefore conclude that every time an abyssal magma has dissolved and assimilated mineral masses, modifying its composition in such a way that the magma has become abnormal, differentiation takes place and the original magma is divided into secondary magmas. On the basis of considerations given in a former paper[4] we may assume that this process of differentiation is governed by the tendency of the magma to separate into magmas having the composition of eutectics and into monomineralic magmas; sometimes the eutectic composition is realized directly, sometimes the original magma is divided into two magmas both of which undergo further differentiation. I propose to give on a subsequent occasion some illustrations of this process; two examples, however, may be cited now—the formation of nepheline-syenites from granites through the assimilation of limestones, according to Daly, and the formation of syenitic rocks from a gabbro-noritic magma by the assimilation of alkali-bearing rock-masses.

[1] W. Brögger, *Die Eruptivgesteine des Kristianiagebiets*. III. Das Ganggefolge des Laurdalits. 1898.

[2] F. Lœwinson-Lessing, "Études de pétrographie générale, avec un mémoire sur les roches éruptives d'une partie du Caucase Central," p. 178: Trans. Soc. Nat. St. Pétersbourg, 1898. "Studien über die Eruptivgesteine," p. 187: Compt. rend. VII Congr. Géol., 1899. See also the Proceedings of the Congress of St. Petersburg, p. clviii.

[3] F. Lœwinson-Lessing, "Petrographical Notices. 3. Is there a difference in the chemical composition of the intrusive and the effusive rocks?": Ann. Inst. Polyt. St. Pétersb., vi, p. 274, 1906.

[4] "Differentiation, Eutectics, and Entropy": loc. cit.

The hypothesis formulated above is the further development of the syntectic-liquational hypothesis (assimilation-differentiation theory), announced by me in 1898. Daly [1] has accepted this hypothesis and made use of it in his paper on the origin of the alkaline rocks. I highly appreciate Daly's endeavour to apply my hypothesis to concrete cases, and I am a supporter of several of his own views. But it is necessary to mention that Daly is wrong in thinking that he enlarges my hypothesis. He cites me as follows: ". . . bisweilen genügt ein Einschmelzen einer unbedeutenden Menge irgend eines fremden Stoffes, der im Magma oder in einem Theil desselben wenig löslieb ist, um einen Anstoss zur Spaltung in mehr oder weniger grossem Maastabe zu geben," [2] and concludes from this passage that I mean only such assimilated masses as are with difficulty, or not at all, soluble in the magma. But from other passages it can be easily seen that I have given to this hypothesis a wider sense, and that there is no 'enlargement' of it in Daly's statements. This may be seen in the whole chapter from which the above passage is cited, and especially from the following passages:—"Dort, wo das Einschmelzen in kleinem Maasstabe stattfindet, zeigt sich die Resorption in der Zusammensetzung des Gesteins durch das Auftreten neuer Minerale oder durch eine Veränderung der relativen Mengen der das Gestein zusammensetzenden Minerale. Dort, hingegen, wo das Einschmelzen von bedeutenden Mengen fremder Gesteinsmassen stattfindet, führt dasselbe ohne Zweifel zu einem Zerfall zur Differentiation des Magmas bei seinem Erkalten," [3] and "dass eine Uebersättigung des Magmas mit einer Gruppe von Basen sich oft nicht durch ein Einfaches Ausscheiden des Ueberschusses ausgleicht, sondern in vielen Fällen eine Spaltung auf irgend welche Weise hervorbringen muss". [4]

And so the question standing at the head of this chapter may be answered as follows:—

1. Differentiation by crystallization is regulated by the density of the minerals in process of formation. The deeper parts of the magmatic basin, where the sunken minerals are dissolved, obtain in this way a somewhat different composition, as has been already expressed by myself [5] and developed by Schweig. [6]

2. The magmatic differentiation taking place in the liquid state is induced by assimilation and governed by the tendency towards the formation of definite magmas which can consolidate as rocks, especially eutectic and monomineralic ones.

3. In the intermediate zones between magmatic masses formed by the processes 1 or 2 a mingling of the two may take place, and

[1] R. Daly, "Origin of the Alkaline Rocks": Bull. Geol. Soc. Amer., xxi, p. 117, 1910.

[2] F. Lœwinson-Lessing, *Studien über die Eruptivgesteine*, p. 188.

[3] Ibid., p. 183.

[4] F. Lœwinson-Lessing, "Kritische Beiträge zur Systematik der Eruptivgesteine: I. Zur Chemie der Magmen": T.M.P.M., xix, p. 299, 1900.

[5] "Studien über die Eruptivgesteine."

[6] M. Schweig, "Untersuchungen über die Differentiation der Magmen": N.J., Beil. Bd., xvii, p. 516, 1903.

from these mixtures there have originated those accidental rocks which can be designated, after Harker, as hybrid rocks.

§ 3. *On the Origin of the Igneous Rocks.*

Let us now consider the third fundamental problem of petrogenesis. What origin have the igneous rocks, and why are they represented by the same types in all periods?

Different geological data and theoretical considerations lead to the conclusion that the identity of the eruptive rocks of all geological periods can be most satisfactorily explained by the assumption that from the Archæan up to the present the eruptive rocks represent nearly the same material, which has been subjected several times to weathering, metamorphism, refusion, and regeneration. The assumption that we find or can find anywhere the primordial solid crust of the globe must be definitely abandoned. The occurrence of clastic and sedimentary rocks in the oldest Archæan formations and numerous examples of refused and recrystallized rocks in these formations eloquently sustain and complete the theoretical considerations which lead us to the conception that the primordial crust has been re-melted long ago, and probably more than once. Such a fusion of parts of the solid crust is sometimes directly attributable to a rising of the isogeotherms at the places in question. In reality the process may be a more complicated one, as can be shown by the following considerations.* A series of sedimentary rocks 30,000 feet thick (the greatest thickness we can admit) would simply by the rising of the isogeotherms acquire in the lowest beds a temperature of 300°, which is quite insufficient for melting these materials. But the geosyncline, where sedimentation of our 30,000 feet of sediments has taken place, may itself consist of an older series of sedimentary material. At a depth of 60,000 feet under the bottom of our geosynclinal the temperature would be 600° C. before sedimentation, and would rise to 900° C. after the deposition of 30,000 feet of sediments. Under the weight of this new sedimentary sheet of 30,000 feet the area in question would probably bend and subside: this would give for a presumable subsidence of 10,000 feet a further increase of 100°, and so the primary temperature would in this way rise from 600° to 1,000° C. All these figures are, of course, hypothetical. But we must bear in mind that epeirogenetic and orogenetic movements can occasion a far greater subsidence of parts of the crust than the process of sedimentation by itself. It is also not to be forgotten that in these great depths the magma is probably rich in water and different gases, and consequently fusible at a lower temperature than the 'dry' magmas generally considered. And, lastly, we must also infer with Suess that the fusion of certain parts of the earth's crust may be produced partly by the rising from below of hot plutonic gases. In short, there are sufficient factors for sustaining the hypothesis that in successive geological periods different parts of the solid crust have been caused to melt, and that by this process have been generated the plutonic and volcanic rocks.

When such a refusion, or 'anatexis' as it is called by Sederholm,[1] embraces a portion of the crust, which consists of definite eruptive rocks, e.g. granite, gabbro, basalt, the resulting magma will again be after consolidation the same rock, perhaps only slightly modified by the assimilation of other material during the passage of the magma to the place where it consolidates. But when the re-melted portion of the crust is composed of different rocks, eruptive or sedimentary, or both together, the process is rather a 'syntexis', as I have called it, an assimilation which is followed by liquation and differentiation; the same process of 'syntexis' or assimilation must take place at the margins of such re-melted portions where they are in contact with non-melted portions. Although I am an advocate of the hypothesis of a fluid nucleus, I do not believe that this nucleus would have been (perhaps with a few exceptions) the source of the Archæan and post-Archæan intrusive bodies and superficial volcanic masses; but certainly it must be admitted that different portions of the solid or anatectic crust can be mixed during the process of refusion with fluid material coming from peripheric magmatic basins.

Thus the face of the solid crust, as far as we know it, has been from the Archæan up to the present time often modified and renewed by weathering, sedimentation, fusion, and recrystallization of the material that had formed the crust in a remote pre-Archæan period lying beyond the limits of direct investigation. No wonder that in all post-Archæan periods, as well as in the Archæan, we meet always the same granitic, syenitic, and basaltic rocks, the same gabbros, diabases, porphyries, etc. It is always the same material, perhaps receiving sometimes an admixture from below, which leads under the influence of assimilation to differentiation, and with a tendency to eutectics, resulting always in the same types of eruptive rocks.

The answer to the question put at the beginning of this section would then be the following: The source whence came the igneous rocks, beginning with the Archæan, is the solid earth's crust, different parts of which, periodically re-melted, have been brought to a magmatic state; these magmas in certain cases correspond directly to further rock-types or are brought to these types by differentiation. Originally the oldest igneous rocks were formed from magmatic masses of granite or gabbroidal composition. Such a conception simplifies our problem, and the identity of rock-types in all periods receives a plausible explanation; but it would be difficult to understand and to explain why in all periods the same rock-types were always formed, if we were to assume that every eruptive rock is a part of the fluid nucleus or of a peripheric magmatic basin, solidified for the first time where we find it now.

When I say that we find in the history of the earth a repetition of the same rock-types, I mean the predominating rock-families, as granites, gabbros, pyroxenites, peridotites, syenites, diabases, basalts, porphyries, etc. But, of course, if we take into consideration that the lithological composition of the crust gets more complicated and

[1] J. Sederholm, "Om Granit och Gneiss": Bull. Comm. Geol. Finlande, No. 23, 1907.

that in younger periods the re-melted parts of the crust were more complicated on account of assimilation and differentiation, we must admit that the number of marginal and local facies and of subordinate rare rock-types will increase as we pass from the older periods to the younger.

The hypothesis that the earth's crust has been subject to melting and refusion has been advocated by geologists, beginning with Hutton, who maintained more than a hundred years ago (in 1788) that the sedimentary materials are metamorphosed and even partly melted, being in this way transformed into eruptive rocks when they come into deeper parts of the crust. During the past few years this conception has been largely developed in the studies of Sederholm[1] on the crystalline schists, and in the work of Lukaschewitch,[2] who discerns in sedimentation, subsidence into the deeper parts of the crust, metamorphism, melting, eruption, weathering, and sedimentation, a complete cycle. It is not my purpose to give here an account of the literature on refusion of the crust, but a few examples of such views amongst modern geologists may be cited.

In his well-known Karlsbad discourse Suess has expressed his opinion that the eruptive rocks do not come from a central liquid nucleus, but that they originated by melting of the crust under the influence of ascending hot gases. In the last part of his *Antlitz der Erde* the hypothesis of refusion (*Aufschmelzung*) is developed in the chapter "Die Tiefen".

Branca[3] also supports this hypothesis, although he would restrict the melting to the deeper parts of the crust, the sedimentary rocks not undergoing fusion. Haug's[4] opinion is that sediments are melted in sinking geosynclines; he thinks nevertheless that the presence of alkalies in the eruptive rocks could not be explained in this way, and that it is necessary to admit also a fluid pyrosphere. Haug's views on granite have already been cited. As to his doubts concerning the alkalies, they cease to apply if we assume, as I have done, that the refusion process attacks not only the parts of the crust composed of sediments but also those which are formed by eruptives. Haug's conclusion that it is necessary to admit a fluid pyrosphere is also not the only possible hypothesis, as separate magmatic basins would explain equally well the peculiarities of igneous rocks.

Dolomieu[5] expressed a similar view when he supposed that trachyte was a re-melted granite, because he found granitic enclosures in the trachyte of the Puy de Dôme. Dutton[6] and Schwarz[7] have also considered lavas as re-melted parts of the crust; and very close to the theory of re-melting are the ideas of Delesse[8] and Sterry-

[1] J. Sederholm, "Om Granit och Gneiss"; Bull. Comm. Géol. Finlande, No. 23, 1907.

[2] O. Lukaschewitch, *The Inorganic Life of the Earth*. Part II, The Life of the Rocks. St. Petersburg, 1909.

[3] Branca, *Centralbl. f. Mineral.*, 1909, p. 135.

[4] E. Haug, *Traité de Géologie*.

[5] Cited by Lacroix, *Mont Pelée*, ii, p. 56.

[6] Dutton, *The High Plateaux of Utah*, 1880, p. 125.

[7] E. Schwarz, "Hot Springs": GEOL. MAG., 1907, No. 480, p. 258.

[8] Delesse, *Études sur le métamorphisme*, 1862, pp. 157–220.

Hunt,[1] who considered the plutonic rocks to be due to thermo-metamorphism.

These fragmentary citations show sufficiently well that at different times different authors relying on different considerations have come to the same conception, namely, that the igneous rocks are to be considered as re-melted parts of the solid crust—a hypothesis which seems to me best fitted to resolve in a satisfactory manner the problem of the genesis of igneous rocks not older than the Archæan.

Conclusions.

1. The method hitherto adopted of calculating the average composition of the terrestrial magma must be considered as erroneous in principle.

2. Nevertheless these calculations give a fairly good result, as it corresponds approximately to the mean between gabbro and granite, if we admit that these two magmas enter into the composition of the external part of the earth's crust nearly in equal quantities.

3. Two original independent magmas exist which predominate in the composition of the earth's crust, the granitic and the gabbroidal (basaltic); all the other igneous rocks are derivates from these two and are subordinate to them in their occurrence.

4. Differentiation is produced in two ways: during the crystallization, differentiation by crystallization; and before crystallization, in the liquid magma—magmatic differentiation.

5. The differentiation by crystallization consists in the sinking or rising of the newly-formed minerals according to their specific gravity, and in the solution in one part of the magma (generally a deeper-seated one) of minerals formed in another part.

6. Magmatic differentiation consists in the formation of derived magmas (*Spaltungen*), and is governed by the tendency to form eutectic and monomineral (or bimineral) magmas. This differentiation is induced by the fusion and assimilation of foreign mineral masses, both igneous and sedimentary.

7. Differentiation finds its best explanation in the syntectic-liquational hypothesis (fusion, assimilation, differentiation).

8. All igneous rocks belong to three types: (1) primordial magmas, (2) rocks due to differentiation, (3) rocks produced by mingling of two magmas.

9. The igneous rocks of all geological periods, presumably from the Archæan, originated principally by the refusion of different parts of the earth's crust. On account of this we meet in successive periods always the same types of rocks. The pre-Archæan igneous rocks (perhaps also a part of those of the Archæan and younger periods) were formed from primordial magmatic masses of granitic and gabbroidal composition.

BEAULIEU S. MER.
January, 1911.

[1] Sterry Hunt, "The Origin of the Crystalline Rocks": Trans. Roy. Soc. Canada, ii, p. 3, 1884.

II.—A new Genus of Fossil Plants from the Stormberg Series of Cape Colony.

By A. C. Seward, F.R.S., Cambridge.

(PLATE XIV.)

THE single specimen which forms the subject of this note was sent to me for examination by Mr. Hewitt, of the Albany Museum, Grahamstown, Cape Colony; it was found at Cyphergat and presented to the Museum by Mr. S. R. Gardner. Fossil plants from Cyphergat in Cape Colony have been described by Feistmantel and, more recently, by myself[1] from beds containing the remains of a flora assigned to the Rhætic age. Our knowledge of this flora is based on material obtained from the Molteno Beds at the base of the Stormberg Series[2] at Molteno, Stormberg, Cyphergat, and other places.

The fossil shown natural size in Pl. XIV, Fig. 1, may be described as follows: A partially carbonized impression of a portion of a bipinnate frond 11 cm. long, consisting of a comparatively slender rachis not exceeding 3 mm. in breadth, which gives off sub-opposite linear pinnæ at an angle of approximately 45°. The pinnæ bear alternate broadly linear pinnules attached by a short stalk; the substance of the lamina is represented in places by a fairly thick carbonaceous layer. The apex of the pinnules is bluntly rounded, and at the proximal end the edge of the lamina bends inwards rather abruptly towards the stalk (Pl. XIV, Figs. 1, 1*a*–*c*). There is a well-defined midrib, from which a few simple or forked veins arise at a wide angle.

The preservation is far from satisfactory, but the thickness of the carbonaceous layer, as seen in some of the pinnules (e.g. Pl. XIV, Fig. 1*a*), indicates a thick lamina. A superficial examination of the specimen suggested comparison with *Bernoullia helvetica*, Heer, a species originally described by Heer[3] from the Upper Triassic beds of Switzerland, and more recently figured by Leuthardt[4] from the Keuper of Neuewelt near Basel. Professor Zeiller[5] has also described the same type from the Rhætic flora of Tonkin. The fertile pinnules of *Bernoullia* are in some cases contracted at the base, and in this respect approach the more definitely stalked segments of the Cyphergat plant; but a more careful examination of the published figures and of a Swiss specimen kindly given to me by Dr. Leuthardt convinced me that the fossils are generically distinct. They differ in the shape of the pinnules as in the venation; in *Bernoullia* the secondary veins are numerous, while in the South African plant they appear to be few and widely separated. Moreover, in the plant shown in Pl. XIV, Fig. 1, the stalked pinnules are sterile, and differ considerably from

[1] Feistmantel, *Abh. kön. böhm. Ges. Wiss.* [vii], Bd. iii, 1889; Seward, Ann. S. African Mus., vol. iv, 1903.

[2] Rogers & Du Toit, *An Introduction to the Geology of Cape Colony*, London, 1909.

[3] Heer, *Flor. Foss. Helvetiæ*, p. 88, pl. xxxviii, figs. 1–6, Zürich, 1876.

[4] Leuthardt, *Abh. Schweiz. paläont. Ges.*, vol. xxxi, p. 38, pl. xix, figs. 1–4; pl. xx, figs. 1, 2, 1904.

[5] Zeiller, *Flor. Foss. Gîtes de Charbon du Tonkin*, p. 34, pl. i, figs. 14–16, Paris, 1903.

T. A. Brock del.

Stormbergia Gardneri, gen. et sp. nov. Stormberg Series, Cyphergat, Cape Colony.

the sterile segments of *Bernoullia*. Among recent ferns stalked pinnules occur not infrequently, e.g. in species of *Adiantum*, *Pellæa*, *Llavea*, *Polybotrya*, *Osmunda*, *Didymochlæna*, and other genera, but it is noteworthy that among fossil Ferns and Pteridosperms stalked pinnules are very uncommon. One of the few examples known to me is *Neuropteris Grangeri*, a species originally described by Brongniart[1] from the Coal-measures of Ohio, and more recently figured by Zeiller[2] from France. In this Upper Carboniferous species the pinnules possess the venation and auriculate base characteristic of *Neuropteris*, and differ widely from those shown in Fig. 1.

It is unfortunate that the South African plant is represented only by a single specimen, and that an imperfect one. While venturing to institute a new genus, I hope that additional material may be obtained which will lead to a more satisfactory knowledge of the affinity of the plant. In the absence of fertile specimens the question of taxonomic position cannot be definitely settled, though the presumption is that the frond is that of a fern.

STORMBERGIA, gen. nov. Plate XIV.

Fronds characterized by pinnules with the *Cladophlebis* type of venation, attached to the pinnæ by a short stalk. The lamina is suddenly contracted at the base and not auriculate.

STORMBERGIA GARDNERI, gen. et sp. nov. Pl. XIV, Figs. 1, 1*a*–*c*.

The specific characters are enumerated in the description already given. The specimen was discovered by Mr. S. R. Gardner in the Stormberg Series at Cyphergat, Cape Colony.

III.—On the Occurrence of Beds of the Yellow Sands and Marl in the Magnesian Limestone of Durham.

By R. Cooksey Burton, B.Sc., Armstrong College.

DURING an investigation of the 'Yellow Sands' and Magnesian Limestone of Durham and Northumberland, several lenticular and irregular hollows or caverns, containing 'Yellow Sands' and light yellow marl, were noticed in the Lower Brecciated Magnesian Limestone at Trow Rocks, about one mile south of the Tyne (see Map, Fig. 1).[3]

The 'Yellow Sands' and marl in some cases are found as separate beds, whereas in others they are mixed together irregularly. The

[1] Brongniart, *Hist. Vég. foss.*, p. 237, pl. lxviii, fig. 1, Paris, 1828.

[2] Zeiller, *Bassin Houill. et Perm. d'Autun et d'Epinac*, p. 145, pl. xi, figs. 6, 6*a*, Paris, 1890.

[3] The classification of the Permian adopted in this paper is as follows:—

7. Upper (Concretionary) Magnesian Limestone.
6. Upper Middle Magnesian Limestone.
5. Brecciated Magnesian Limestone of irregular thickness.
4. Disturbed beds of Lower Limestone.
3. Undisturbed Beds of Lower Limestone.
2. Marl Slate.
1. Yellow Sands.

The 'Yellow Sands' lie unconformably on the Coal-measures.

'Yellow Sands', even when regularly bedded, contain a considerable amount of calcareous marly material, being in this respect rather different from the 'Yellow Sands' as they outcrop in the normal position beneath the Marl Slate and Magnesian Limestone. When, however, the sand from these included beds is washed with acid, there is no difficulty in recognizing the well-worn and rounded grains of the typical wind-blown 'Yellow Sands'.

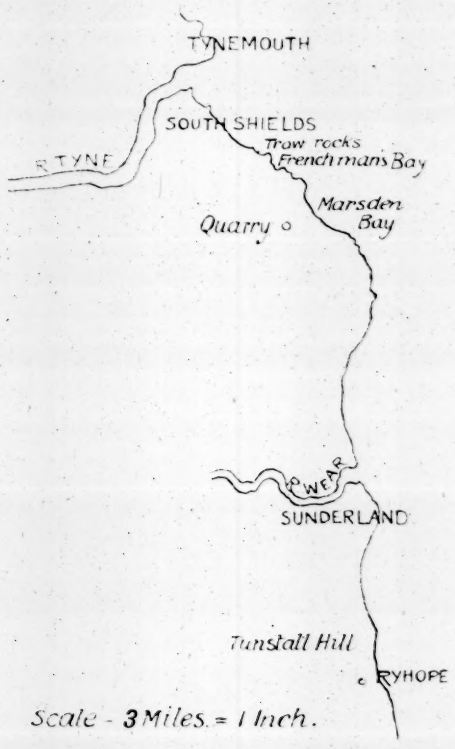

FIG. 1. Sketch-map showing places mentioned in this paper.

The manner in which the deposits occur in the breccia is difficult to describe, as they are very variable in shape; but it will be convenient to recognize three classes—

1. 'Yellow Sands' and yellow marl occurring in small pockets and hollows in the Breccia.

2. Irregular beds lying in horizontal and nearly vertical and parallel fissures, all filled with 'Yellow Sands' mixed with marl in various proportions.

3. Lenticular and cavernous hollows filled by alternating beds of 'Yellow Sands' and marl.

1. The small pockets and hollows are of various dimensions, having a diameter from 2 to 5 inches; these pockets form a network simulating an irregular honeycomb structure. In these small pockets the sand and marl are irregularly mixed together, so that no regular bedding can be distinguished.

2. The second type is shown in Fig. 3, where highly inclined parallel fissures are connected with the main horizontal fissure. The included beds consist mainly of impure 'Yellow Sands', becoming more marly towards the ends. The bedding is conspicuous and conforms very noticeably to the irregular roof.

3. Fig. 4 shows a section of the thickest and most extensive of the lenticular beds of 'Yellow Sands'; its total thickness is 4 feet and its length slightly more than 20 feet; it is remarkable as showing alternations of sand and marl in well-bedded horizontal layers and in presenting a well-marked case of false bedding in the sand (see A, Fig. 4). The marl is quite moist and soft and contains a considerable amount of common salt. The water pumped up from considerable depths in the Permian is generally salty, and its specific gravity sometimes approaches that of sea-water.

The area over which these peculiar included beds of 'Yellow Sands' are scattered is fairly extensive, and the fact that both in the north–south and east–west sections their shape is lenticular is an argument in favour of their occupying cavern-shaped hollows in the breccia. More than a dozen of these pockets filled with sand and marl are scattered over the Trow Rocks area.

The 'Yellow Sands' as they occur in situ beneath the Marl Slate consist of well-polished and rounded grains of quartz coated with oxides of iron, which give to the sand various colours from light yellow to dark brownish-red according to the percentage and state of hydration of the iron oxide. The sand from the above pockets and lenticular beds was identified with certainty as true 'Yellow Sands' not only by the rounded nature of the grains, but also by a comparison of the percentage of its heavy minerals with that peculiar to the 'Yellow Sands' occurring in their natural position at Frenchman's Bay, half a mile to the south.

The 'Yellow Sands' all along their outcrop contain varying percentages of heavy minerals having a specific gravity greater than 2·80; these were determined by the use of Sonstadt solution in Sollas's separating funnel. At Frenchman's Bay the percentage of heavy residue is 0·17 per cent., while in the Trow Rocks 'Yellow Sands' it is 0·2 per cent.; in each case the heavy minerals are similar, being mainly garnet, tourmaline, zircon, rutile, and ilmenite, with leucoxene.

It is thus established that the sand occurring in the pockets in Magnesian Limestone at Trow Rocks is identical with the bed of 'Yellow Sands' which occurs in place at Frenchman's Bay between tide-marks. The light-yellow marl is a mixture of calcium and magnesium carbonates containing clayey matter in varying quantities. So far as our knowledge extends at present the 'Yellow Sands' are invariably accompanied by the Marl Slate when in their natural position, being directly under this group of beds, which occurs at the base of the

Magnesian Limestone. In the present instance, however, the Marl Slate is absent for reasons given in detail below. At Frenchman's Bay the 'Yellow Sands' outcrop about 20 feet below the level of the cliff foot, and at Trow Rocks the above-mentioned included beds of 'Yellow Sands' occur at various heights (4–30 feet) above the base of the cliff, so that these beds are sometimes as much as 50 feet above their natural position. The following are possible explanations of their mode of formation:—

1. The sand may be the residue left on the solution of the Magnesian Limestone.

2. The sand may have been carried up from beneath the Marl Slate by the thrusting movements.[1]

3. The beds may be a later deposit of 'Yellow Sands' laid down in the positions in which we now find them.

4. They may have been carried up from below by the action of underground water.

We will deal with these suggestions in order.

1. While studying the mineralogical composition of the 'Yellow Sands' we have examined many samples of Magnesian Limestone, and in some cases they have been proved to contain quartz grains and various heavy minerals, which we hope to describe at some future date. These Magnesian Limestone grits occur at Rocky Crag, Tunstall Hill, in the form of a vertical dyke-like mass, at Marsden Quarry as a horizontal bed in the Middle Magnesian Limestone, and in a cave in Marsden Quarry about 40 feet above the level of the last. In all these cases, however, the residue left from the limestone after treatment with acid consists of angular and rounded grains of various sizes from $\frac{3}{16}$ inch to microscopic proportions; the angular grains are among the largest, and consist of quartz, chalcedony, and chert. This sand is evidently not wind-blown but deposited by water, and could not be mistaken for the 'Yellow Sands', since in the latter the largest grains are perfectly rounded and abraded; the smaller grains of the 'Yellow Sands' are sometimes quite angular. This, however, is in accordance with Sorby's statement that the smallest grains in a sand are always the most angular, as they present only a small surface for abrasion. It is thus evident that the beds of 'Yellow Sands' are not insoluble residues left on the solution of the Magnesian Limestone. As regards the origin of the chert in these sandy residues, it may be stated that we have lately discovered in the brecciated Magnesian Limestone, nodules, irregular beds, and brecciated pieces of chert. On the coast half a mile north of Ryhope a thin brecciated bed of white chert occurs 30 feet long and 6 inches thick; it is irregular and forms part of the breccia, although not so strongly brecciated as the limestone owing to its being of stronger material.

[1] The effects of the horizontal thrust on the Permian of this area have been fully described by Dr. Woolacott in Memoir No. 1, Durham University Philosophical Society. For our purposes it is sufficient to state that considerable horizontal movement of the upper beds of limestone has taken place over the lower, causing brecciation of the lower and middle Magnesian Limestone; part of the lower limestone lying under the thrust-plane is slightly disturbed, but remains unbrecciated.

At Marsden large angular blocks of white chert, sometimes 9 inches in diameter, have been found, and at Trow Rocks smaller pieces of white and also black chert are met with. It is worthy of note that this chert is always seen in the Middle Brecciated Magnesian Limestone; this, coupled with the facts above mentioned, proves that the chert is of pre-Thrust age and probably contemporaneous with the limestone.

2. The second suggestion is untenable, since the sand and marl could not have been carried up during the movement of the rocks caused by the thrusting, because the beds are quite undisturbed, regularly bedded, and laminated; moreover, the existence of false-bedding in the sand points to deposition in water disturbed by only slight currents.

3. At first sight this theory seems to be plausible, the more so because at Tynemouth Cliff we find beds of 'Yellow Sands' above the lower beds of Magnesian Limestone. Below is a sketch of the Tynemouth Cliff section, showing the position of the later beds of 'Yellow Sands'.

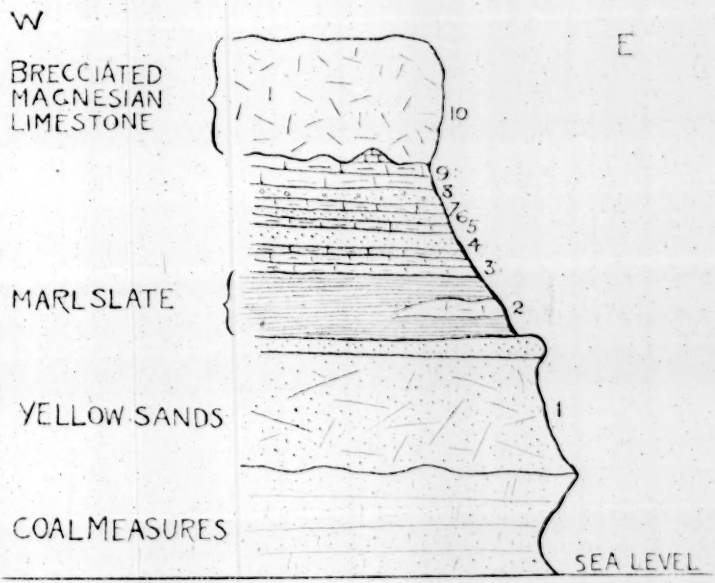

FIG. 2. Section of Tynemouth Cliff. 1, Lowest bed of Yellow Sands, 12 feet; 2, Marl Slate, 4 feet; 3, Thin-bedded Magnesian Limestone; 4, Yellow Sands, 2 feet; 5, Thin Magnesian Limestone; 6, Yellow Sands, 3 inches; 7, Thin Magnesian Limestone; 8, Uppermost bed of Yellow Sands, 1½ feet; 9, Bedded Magnesian Limestone; 10, Brecciated Magnesian Limestone, 20 feet.

This section has been frequently misinterpreted; in Sedgwick's paper on the Geological Relations and Internal Structure of the Magnesian Limestone[1] the Marl Slate is represented as overlying certain beds

[1] Q.J.G.S., ser. II, vol. iii, pl. vi, fig. 1, 1835.

of Magnesian Limestone; this, however, is not the case, the Marl Slate is here in its proper position above 'Yellow Sands', but is itself overlain by later beds of 'Yellow Sands' separated by thin beds of Magnesian Limestone. The correct section is shown in Fig. 2. The uppermost bed of 'Yellow Sands', No. 8, is very compact and should rather be termed a Magnesian Limestone grit or conglomerate; it consists of large and small grains and pieces of more compact 'Yellow Sands' cemented into a solid rock by a dark-yellow cement of magnesium and calcium carbonates; it represents the latest stage of the deposition of 'Yellow Sands', and was probably produced by 'Yellow Sands' being blown and otherwise carried into water, in which the deposition of Magnesian Limestone was proceeding. A local unconformity between the 'Yellow Sands' and Magnesian Limestone is therefore proved at this point. The

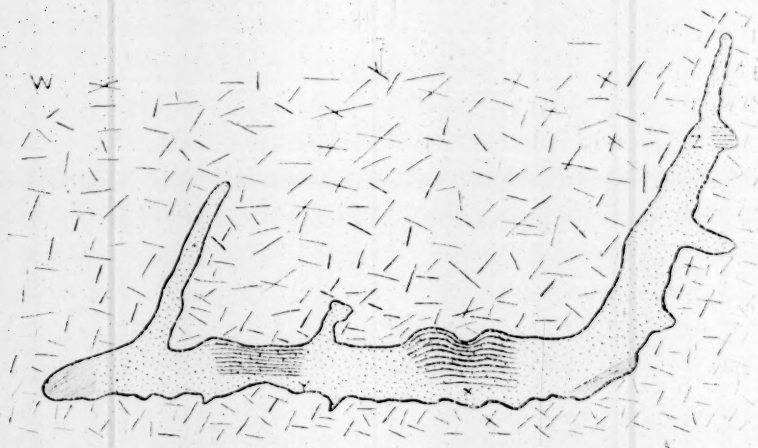

Fig. 3. Fissures in the Magnesian Limestone containing Yellow Sands. Dotted portion, Yellow Sands; shaded portion, Marl predominating; bedded sand at X, Y, Z. Length of section, 15 feet; thickness of sand at X, 1½ feet; cross-hatching, Brecciated Magnesian Limestone.

occurrence of these beds of sand, Nos. 4, 6, and 8, above the Marl Slate and also above certain beds of Magnesian Limestone proves that the formation of 'Yellow Sands' proceeded, perhaps intermittently, during the deposition of the limestone; thin beds of 'Yellow Sands', one inch thick, sometimes occur between the bedding-planes of the limestone just above the Marl Slate, but they rapidly thin out to nothing.

4. We will now discuss the last and most satisfactory explanation of the occurrence of these secondary beds of 'Yellow Sands'. This series, as has been shown by many writers,[1] is a great water-bearing system, and is the source of the water-supply of Sunderland and most

[1] Professor Lebour, Trans. N. of England Inst. Min. Eng., vol. xxiv, p. 370, 1902-3.

of the neighbouring region. Now when the thrust[1] acted on the Permian rocks of this area the Magnesian Limestone and Marl Slate were much disturbed, brecciated, contorted, and pinched out in various ways; fissures were produced, much shearing and slickensiding took place, and opportunities for the circulation of water were greatly increased. At Trow Rocks the thrust-plane can be seen at the north end of the quarry dipping to the south, and we find brecciated Magnesian Limestone overlying unbrecciated beds beneath the thrust-plane. The Marl Slate and 'Yellow Sands' cannot be seen in situ, being below tide-mark, and the effect of the thrust on those beds cannot be exactly determined at this point. The Marl Slate is a relatively impermeable bed, and would, no doubt, in its normal

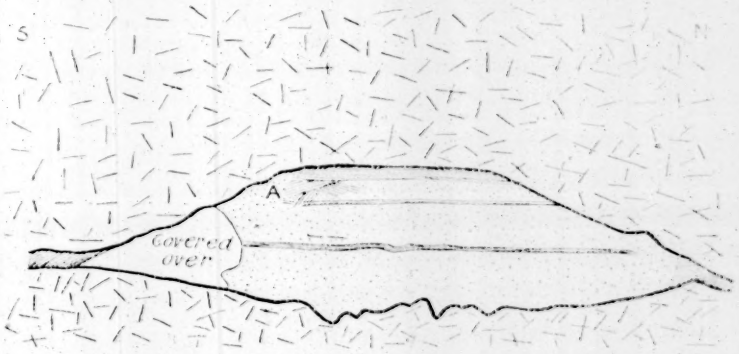

FIG. 4. Section of lenticular hollow in the Magnesian Limestone, containing Yellow Sands. The Marl beds are 2 inches to 3 inches thick; total thickness of lenticular bed, 4 feet; total length of lenticular bed, 20 feet.

condition prevent the circulation of much water through it. The Marl Slate at Trow Rocks must therefore have been so fractured and possibly brecciated by the thrusting movements that water could freely percolate through it and through the joints. In many sinkings made in the North of England Permian water in large quantity has been struck, and in its rise from below has carried up large amounts of 'Yellow Sands'; it is thus that the lenticular beds of sand and marl in the Magnesian Limestone have been formed. Subsequent to the brecciation of the rocks percolating water has excavated hollows in the breccia; underground water has accumulated to heights of at least 50 to 60 feet above the 'Yellow Sands', and, being probably subject to rises and falls for some unknown reasons, has carried up with it quantities of the loose sand and deposited it in the above-mentioned hollows and caverns, and thus formed secondary beds of 'Yellow Sands'.

In all cases the beds of 'Yellow Sands' and marl conform to the irregular surfaces of the limestone and also quite fill the hollows,

[1] Dr. Woolacott, "A case of Thrust and Crush-brecciation in the Magnesian Limestone of County Durham": Univ. Durham Phil. Soc., Memoir No. 1.

so that the water carrying the sediment must have quite filled the hollows. The secondary beds are found as much as 50 feet above the outcrop of the 'Yellow Sands', so that the underground water must have risen to at least this height and have filled the joints, fissures, and caverns in the limestone breccia. Some of the sand beds contain angular blocks of breccia, which have doubtless fallen from the roof of the cavern during the deposition of the secondary beds. The thrust-plane mentioned above was seen to affect only the upper beds of the lower limestone, while the beds beneath were unbrecciated; the Marl Slate is thus probably unaffected by this thrust-plane, being several feet below it. We have seen that the Marl Slate must be disturbed and fractured, and in order to account for this we may assume the existence of a second thrust-plane beneath the first along which the Marl Slate and possibly lower beds have been set in motion and fractured. The section from the Tyne southwards shows many interesting breccias, and at Trow Rocks evidence can be obtained proving that at least two series of thrust movements, and possibly three, have affected the Permian of this area. In the first place some pieces of breccia contain within them angular fragments of breccia produced by a previous thrust-movement; the limestone was first brecciated, and the breccia, having been cemented into a compact rock, was subsequently broken up by a second series of movements. Moreover, the breccia as a whole is traversed in some places by a series of joints, reversed faults, and other slickensided planes of movement, which may have been formed during a third movement of the beds in a horizontal direction. The thrust-plane, which affects the Magnesian Limestone and is seen dipping south at the north end of Trow Rocks, probably crosses the Marl Slate somewhere to the south of Trow Rocks; the 'Yellow Sands' in the pockets may therefore have been carried up by water from this point and not from a place immediately below their present position; it would then be unnecessary to assume a second thrust-plane to account for this phenomenon, but the occurrence of the above-mentioned doubly brecciated rocks renders it probable that there is a second thrust-plane in the Coal-measures or in the Lower Permian beds.

The whole question of the origin of marl pockets in the Magnesian Limestone may be affected by the discovery of the above secondary beds of 'Yellow Sands'.

Bedded 'Yellow Sands' in marl pockets have not before been proved; moreover, the existence of pockets, as at Marsden, containing marl and angular sand-grains renders it probable that many marl pockets are of secondary origin due to solution of the limestone, and the subsequent washing in of marl and the insoluble residue left on solution of the limestone. Many marl pockets are, of course, original and are particularly rich in Permian Gasteropods and Foraminifera: such pockets are known at Tunstall Hope and have yielded, among others, specimens of *Textularia* and *Turbo Taylorianus*.

In conclusion I desire to express my thanks to Professor Lebour and Dr. Woolacott for their well-timed criticism and encouragement.

IV.—On a New Species of *Eryon* from the Upper Lias, Dumbleton Hill.

By Henry Woodward, LL.D., F.R.S.

VARIOUS forms of Macrourous Decapod Crustacea referable to the genus *Eryon* have attracted my attention from an early date,[1] and in the Geological Magazine for 1888[2] I gave a summary of all the then known species. The following seven species are British:—

Eryon (*Coleia*) *antiquus*, Broderip, sp., 1840. Lower Lias, Lyme Regis.
E. Barrovensis, M'Coy, 1849. Lias, Barrow-on-Soar.
E. Brodiei, H. Woodw., 1866. Lower Lias, Lyme Regis.
E. crassichelis, H. Woodw., 1866. Lower Lias, Lyme Regis.
E. Wilmcotensis, H. Woodw., 1866. Lower Lias, Wilmcote.
E. Moorei, H. Woodw., 1866. Upper White Lias, Ilminster.
E. Stoddarti, H. Woodw., 1881. Stonesfield Slate, Oxfordshire.

The sixteen species given below are all foreign:—

Eryon Escheri, Oppel, 1862. Lower Lias, Schambelen, Switzerland.
E. Edwardsi, Moriere, 1864. Upper Lias, Calvados.
E. Calvadosi, Moriere, 1883. Upper Lias, Calvados.
E. Hartmanni, v. Meyer, 1862. Upper Lias, Boll, Würtemberg.
E. Perroni, Etallon, 1858. Oxfordian, Haute Saône.
E. arctiformis, Schlot., 1820.
E. bilobatus, Münst., 1839.
E. elongatus, Münst., 1839.
E. longipes, Fraas, 1855.
E. Oppeli, H. Woodw., 1866. Kimmeridgian Group, Lithographic Stone, Solenhofen.
E. orbiculatus, Münst., 1839.
E. propinquus, Schlot., 1822.
E. Redenbacheri, Münst., 1839.
E. Schuberti, v. Meyer, 1836.
E. spinimanus, Germar, 1827.
E. Neocomiensis, H. Woodw., 1881. Lower Cretaceous, Silesia.

I have recently received from Mr. Linsdall Richardson, F.R.S.E., F.G.S., the Honorary Secretary of the Cotteswold Naturalists' Field Club, Cheltenham, a specimen of *Eryon* from the Upper Lias of Dumbleton Hill, near Beckford, Gloucestershire (see Fig. 2), which appears to represent a species of that genus new to this country, but closely allied to a small group comprising three species, namely, *Eryon propinquus*, Schlot., sp., *E. orbiculatus*, Münst., and *E. elongatus*, Münst., all from the Lithographic Stone of Solenhofen, in Bavaria, and of Kimmeridgian age, characterized by the more rounded form of their carapaces when compared with such species as *E. Barrovensis*, M'Coy, *E. Brodiei*, H. Woodw., *E. antiquus*, Broderip, sp., and *E. arctiformis*, Schlot., sp.

We subjoin a figure of the under-side of *Eryon propinquus*, Schlot., sp. (Fig. 1), from the Lithographic Stone of Mörnsheim, near Solenhofen, Bavaria (see Oppel's *Pal. Mittheil.*, 1862, tab. i, fig. 2). In this specimen all the appendages are most beautifully preserved—indeed, quite as well as in a living form. Two specimens, almost equally perfect, may be seen in the Haberlein Collection, also from the Lithographic Stone of Solenhofen, in the British Museum (Nat. Hist.), Department Geology, Gallery VIII, Wall-case Crustacea.

[1] See Quart. Journ. Geol. Soc., vol. xxiii, p. 493, pls. xxiv, xxv, 1866.
[2] pp. 433–41, Pl. XII and Text-figs.

Dr. W. T. Calman[1] places the Eryonidea under the

Sub-order 2. REPTANTIA, Boas (1880).

"Body not compressed, often depressed; rostrum often absent, depressed if present; first abdominal somite distinctly smaller than the rest; legs strong, the first pair usually, the others never, stouter than their fellows, basipodite and ischiopodite almost always coalesced in the first pair, generally also in the others, two fixed points in the carpo-podal articulation, exopodites never present, podobranchiæ often on some of the first four pairs; male genital apertures on coxopodites or on sternum; pleopods often reduced or absent, not used for swimming."

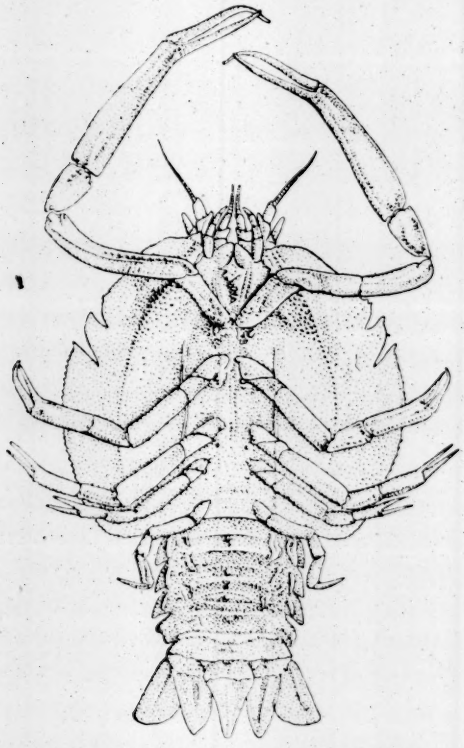

FIG. 1. *Eryon propinquus*, Schlot., sp. Lithographic Stone: Solenhofen, Bavaria.

[Reproduced by permission from Sir Ray Lankester's *Treatise of Zoology*, pt. vii, Appendiculata, fasc. iii, Crustacea, by Dr. W. T. Calman, p. 308, fig. 185.]

Section 1. PALINURA.

Tribe 1. ERYONIDEA.

"Antennæ with exopodite, first segment not fused with epistome, first four pairs, or all the legs, chelate, first pleopods present."[1]

[1] See in Lankester's *Treatise of Zoology*, pt. vii, Appendiculata, fasc. iii, Crustacea, by W. T. Calman, 1909, p. 312.

Condition of the specimen.—The Dumbleton specimen is a natural counterpart of the under-side of the carapace, carrying with it the greater part of the test, and thus exposing an inner view of it and of the three anterior segments of the abdomen attached to it; the minute punctate ornamentation of the surface being caused by the observer

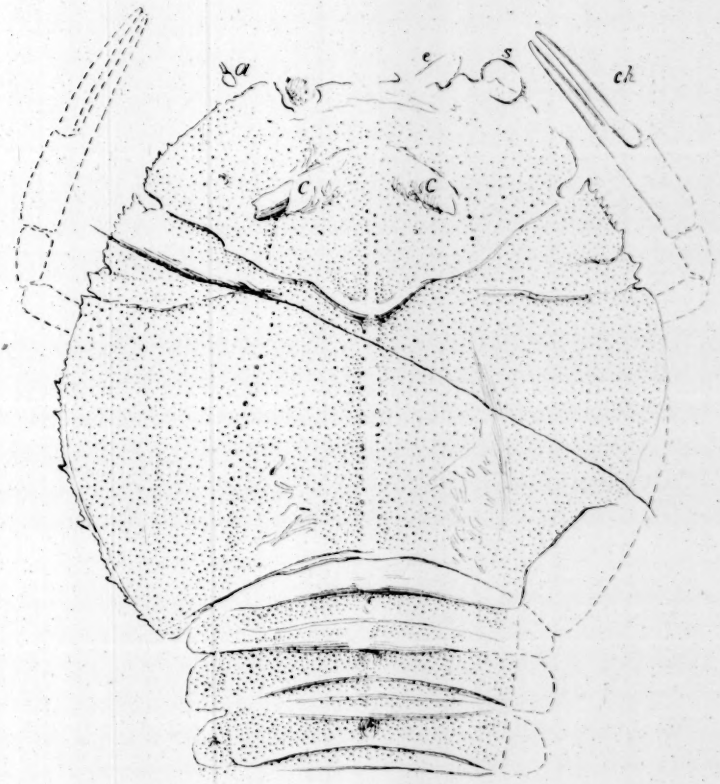

FIG. 2. *Eryon Richardsoni*, sp. nov. Nat. size. Upper Lias: Dumbleton Hill, near Beckford, Gloucestershire. *a*, portion of one of the antennules detached; *e*, scale at base of right antenna; *s*, section of a broken limb detached and displaced; *c*, *c*, part of basal joints of large chelæ; *ch*, portion of large chela on right side (the missing parts of both chelæ are restored in dotted lines).

seeing the under-side of the finely tuberculated free surface, which is still partly adhering to the matrix and partly to the other corresponding slab which is evidently missing. The breadth of the carapace is rather greater than the length, its contour being nearly circular; the posterior border is arcuate and broadly incurved, the postero-lateral border is rather contracted, and its angles slightly produced

backwards. The margin along the branchial region is entire, broadly and gently rounded, its border finely serrated, having five or six rather larger spines at irregular intervals. The carapace contracts slightly in breadth towards the cervical ridge[1] where the first marginal indentation is seen, in front of which is a small, rather obtuse, marginal tooth, marked by a slight notch in front and by a branch of the cervical 'furrow' behind; this is succeeded (anteriorly) by a second roundly incurved marginal tooth, twice the breadth of the last one, with a rounded border and sharply pointed spine directed forwards and marked off anteriorly by a well-defined notch and by the superior branch of the cervical 'furrow'.[1] The margin again expands slightly, and then curves rapidly inwards until it forms with a spine the outer angle of the orbital fossa. The anterior frontal border (with the antennules and antennæ) has been much crushed and can only be imperfectly defined. The eyes are not preserved, but on the right side there is a portion of one of the large chelæ seen in section lying in the orbital fossa (*s*). Width of the anterior border of carapace, 3 cm.; width across the broadest part of the carapace (behind the cervical ridge[1]), 9 cm.; width at posterior border, 6 cm.; length of carapace along the dorsal line, 7 cm. The cervical ridge occupies its centre and forms a concave curve backwards 15 mm. in breadth, being 3½ cm. behind the anterior and 3¼ cm. in front of the posterior border. It bifurcates at 10 mm. on either side of the dorsal line, enclosing between its branches the two tooth-like serrations on the lateral border. Two curved furrows[2] cross the posterior portion of the carapace, the inner pair at 15 mm. distance on either side of the straight dorsal line at the hinder border, but converging to 10 mm. at the cervical furrow; the outer pair are more faintly marked. The dorsal ridge and the two lateral lines nearest to the dorsal line (marked by slightly larger tubercles) extend from the cervical furrow to the anterior margin of the carapace.

Traces of the basal joints of the large anterior pair of chelate legs are seen on the anterior part of the carapace at *c*, and one of the chelæ is seen upon the slab in its normal position (*ch*). The three anterior abdominal segments still remain attached to the cephalothorax, and measure together 3½ cm. in length and 5 cm. in breadth. Each segment is broadest near its margin, and is strongly corrugated transversely, the back and front ridges of each segment converging on the dorsal line, and each segment is marked by a very prominent tubercle which we see as a hollow on the under-side. These transverse ridges and furrows give attachment to the muscles for flexing the abdominal segments and the rhipidura or tail-fan in swimming. The central portion of each segment is ornamented with minute tubercles, but the interlocking and overlapping anterior and posterior borders are smooth.

[1] This would, on the exposed upper surface of the carapace, be seen to be a furrow, but is here seen from beneath as a ridge.

[2] But for the fact that we are looking at the under-surface, both the dorsal and lateral furrows would appear as ridges upon the upper surface of the carapace, whilst the cervical furrow (which is really a furrow) appears as a ridge when seen from underneath.

When compared with other species of the genus, so far as its imperfectly preserved condition admits, we notice that the Dumbleton specimen (Fig. 2) has a small additional posterior tooth upon the margin of the carapace near the cervical furrow, and that the cervical furrow is distinctly bifurcated. This is seen to be the case in *Eryon Moorei*, H. Woodw. (Q.J.G.S., vol. xxii, p. 499, pl. xxv, fig. 3, 1866), in *E. Brodiei*, H. Woodw. (op. cit., p. 498, pl. xxiv, fig. 2); probably also in *E. crassichelis*, H. Woodw. (op. cit., p. 497, pl. xxv, fig. 2), and in the recent *Pentacheles euthrix*, W. Suhm, "Challenger" Report (see also Geol. Mag., 1888, p. 439, fig. 2), but not noticeable in the other species of this genus.

Although the above characters may be considered minor distinctions, yet, taken along with the fact of the extremely rounded contour of the carapace in the Dumbleton specimen (Fig. 2), a feature observed only in three, or possibly four, other species (for *E. crassichelis* may perhaps also have had a rather circular carapace), and being probably the first of these circular forms of *Eryon* observed in our English Lias, I venture to designate it as *E. Richardsoni* after its discoverer, Mr. Linsdall Richardson, F.R.S.E., F.G.S., the energetic Secretary of the Cotteswold Club, to whom I am indebted for the opportunity to figure and describe it.

The specimen is to be placed in the Cheltenham Town Museum, and forms a part of the 'Holland Collection'.

REVIEWS.

I.—A New Vulcanology.[1]

(*Concluded from the June Number, p. 273.*)

We now come to the portion of the book which will attract most attention, the portion, that is, which deals directly with the function of water in volcanic phenomena. An account is given of the methods employed in the *quantitative determination of water in natural volcanic emanations*. Two methods are used in the field—(1) condensation, (2) hygrometry. Specimens are also taken in sealed tubes to the laboratory, and there examined either hygrometrically or by absorption over phosphoric anhydride.

The wealth of experimental and observational data which follows may be illustrated by a few selected examples. Brun's main thesis is that paroxysmal eruptions are *anhydrous*, while solfataric eruptions owe their *aqueous* character solely to the invasion of volcanic foci by superficial waters as soon as the temperature of the latter falls sufficiently.

A summary of observations made at *Vesuvius* in April, 1906, may be taken as typical.

1. Near the crater the ashes fell quite dry. They continually gave rise to avalanches, and once they were mixed with the air in this manner they entrapped myriads of bubbles, forming an emulsion which

[1] *Recherches sur l'exhalaison volcanique*, by Albert Brun, Chemist, L.Sc.Ph. Sorbonne, D.Sc.Ph. (*honoris causa*) Geneva. A large quarto volume, 227 pages, 16 text-figures, 27 photographic plates, and 7 panoramas. Price 30 francs.

settled with extreme slowness. Photographs show the author wading through such emulsions well over his ankles. At a distance from the crater, for example at Pompeii, the ash fell with 0·1 per cent. water and was sufficiently moist to retain a finger-print. This increasing water content depends upon the presence of the hygroscopic chlorides $Fe\,Cl_2$, $Mg\,Cl_2$, etc. Where it has 0·2 per cent. water the ash agglutinates into little spheres. The hygroscopic character of the ash is well shown by the following experiment. After careful drying the ash is exposed to a moist atmosphere saturated at 20° C. (P. = 730 mm.). It absorbs—

In 5 minutes	. . . .	0·13 per cent. of water.
,, 15 ,,	. . . .	0·30 ,, ,,
,, 60 ,,	. . . .	0·90 ,, ,,

Those who maintain the orthodox aqueous theory of volcanic explosions must suppose that the ash falling near the crater was too hot during its transit to absorb any of the water-vapour by which it was propelled. This involves another difficulty: the ash when it falls is white, but it can be shown experimentally that owing to its content of ferrous chloride, it reddens immediately if exposed to the action of water-vapour at a high temperature.

2. In the mass of the cone and in the crater the salts $Fe_2\,Cl_6$, $Fe\,Cl_2$, $Mg\,Cl_2$, and $Al_2\,Cl_6$ may be collected dry and undecomposed, although at low temperatures they are deliquescent, while at 300° C. water-vapour transforms them instantaneously into $Fe_2\,O_3$, $Mg\,O$, and $Al_2\,O_3$.

3. One day during the eruption drops of moist clay did indeed fall at Resina; at other places, however, the ash was dry. The local nature of the phenomenon points to the atmosphere as the source of the water in this particular case. The very darkness due to a cloud of ash is in itself a provocative cause of rain, owing to the fall in atmospheric temperature involved; thus Brun and Montagnier have observed drops of clay during a sandstorm at the Bay of Peneda, Lanzarote, one of the Canary Islands, whither we may now follow our indefatigable guide.

Brun went to the Canaries with Montagnier on purpose to study volcanoes in a typical arid region. Solfatara were found on the *Sugar Loaf* of Tenerife. Those of the crater had a temperature of 83° C., and liberated gases which, when deprived of water, had a percentage volume composition of about 67 per cent. CO_2, 4 per cent. O_2, and 29 per cent. unabsorbable gases (nitrogen, etc.). The water saturated the fumaroles after showers of rain, and in fact occurred as drops carried in the stream of gas; at other times its amount was insufficient to maintain saturation.

Timanfaya, in Lanzarote, proved exceptionally interesting. Rain falls but once a year in this island, and at the time of Brun's visit, in mid-September, 1907, the last rain had fallen on April 27, and had continued for four hours only.

The cone of Timanfaya is a mass built up of lapilli, dating from the eruption of 1730–6, and is still warm (1907). Where the temperature is highest the pebbles are cemented into a reddened crust 10 cm. deep. The base of this crust is covered with a thin green

layer of ferrous chloride, and has a temperature of about 140° C. Below there occur black lapilli covered with a white saline crust. At 60 cm. the temperature is already 360° C.

There are no fumaroles. Burying the tubes as deeply as possible in the lapilli, the gas pumped up proved to be nothing but air with a trace of carbon dioxide and ammonia. The dew-point of the air thus obtained was 16° C., that of the atmospheric air at the same locality 16°·5 C. This experiment, and the preservation of the ferrous chloride on the lapilli, afford evidence that the volcano, though hot, is exhaling no water. As it is scarcely exhaling any vapour or gas at all this observation is in a sense negative, but it can scarcely be doubted that were Timanfaya transported to a humid region it would give rise to the commonplace solfataric phenomena.

Once again the scene changes as we follow our explorer to the soaking tropical region of Java. As before only a few selected observations can be mentioned. The giant *Semero* is climbed. The destructive deluges of mud which descend its slopes are only indirectly volcanic in origin. Since its recent reawakening Semero has cleared its upper slopes of vegetation and thus has given a free hand to pluvial erosion.

The great white cloud of the volcano slowly drifts out of sight beyond the horizon. It is insoluble in the atmosphere and therefore consists of solid particles, not of condensed water-vapour. This is a point Brun emphasizes repeatedly in connexion with active volcanoes in general. It has, however, long been noticed that the appearance of Stromboli and Vesuvius is markedly dependent upon weather condition, and Brun in a later portion of his book alludes to this phenomenon, accounting for it by postulating a condensation of atmospheric water on hygroscopic salts contained in the anhydrous fumes. A critic may well ask: if the salts in the fumes can on occasion condense atmospheric water, can they not also be relied upon to condense and retain the magmatic water with which, according to orthodox opinion, they are closely associated? It seems wise, then, not to rely too far upon the insolubility of the great white cloud as seen from a distance. Brun's researches carried out actually within the cloud at Kilauea are therefore all the more welcome, but before we can deal with these there are other points to notice in regard to Semero and its Javanese companions.

Semero itself was in a paroxysmal phase when visited. The rim bathed in fumes gave rise to no aqueous condensation, although its surface temperature, observed at 7 o'clock in the morning, was only 5° C. The ashes fell perfectly dry. Aqueous fumaroles were noticed, but they had no deep roots; they occurred at the junction-line of the dry region round about the active foci and the moist plateau region beyond. Their fumes dissolved freely in the air.

Papandajan furnishes a striking instance of the solfataric phase. The crater has a vast undulating floor cut up by stream channels and surrounded by a wall 100 to 300 metres high, breached at the east by the eruption of 1772. The hottest solfatara occur on a little hillock built up of broken pebbles of old lavas much altered; pure opal has frequently been produced at the edge of this hillock.

The solfatara are found to be increasingly hot according as one approaches the centre of the hillock mentioned above. At a distance warm streams and springs occur. At 300 metres from the centre springs at 92° C. were met with, and so on until further advance was precluded owing to hot penetrating acid fumes emitted at a temperature of 270° C.

Leaving out of account the many interesting phenomena connected with the deposition of sulphur, and in the high temperature zone of realgar, we shall restrict our attention to the pressure of the water-vapour in these solfatara. From 92° to 120° C. the vapour pressure of the water mounts rapidly; from 120° to 270° C. it falls no less rapidly. There is no support, therefore, for the common idea that the source of heat is the source of water.

At the time of Brun's visit in 1908 *Tjiwidey*, another Java volcano, was supplying a diagrammatic vindication of his views regarding solfataric water. A cold stream leapt into the warm central region of the crater, and scattering on the little solfataric plain, emerged steaming and charged with milk of sulphur. Other examples are cited where crater lakes have established themselves, and these too are useful in driving home the argument.

And now for *Kilauea*, the most obliging of volcanoes, paroxysmal and yet not dangerous!

Brun's first experiment consisted in sucking up the fumes from the crater pit through the glass tube system already described. Salts were deposited along the whole length of the tubing, but no trace of moisture.

His second experiment was even more striking. He took a series of dew-point readings within and without the great white cloud as the latter drifted across the rim in a steady stream carried by the prevailing trade-wind; his results, expressed in curves, show in every case a lower dew-point for the air entangled in the cloud than for the normal atmosphere outside. He also collected specimens from the pit itself in vacuum tubes, and, testing them later on in the laboratory, found a like deficit in regard to water. Leaving the rim of the pit he next visited one of the peripheral aqueous fumaroles, situated, as at Semero, where the volcanic heat travelling outwards meets the general pluvial moisture of the mountain mass. Here he obtained, as was to be expected, exactly the reverse result, to wit, a markedly elevated dew-point.

The lowering of the dew-point in the great white cloud of Kilauea is an observation which cannot long go untested. Meanwhile it is difficult to see how a mistake can have crept in to vitiate a whole series of experiments. Brun naturally interprets his result as a further proof of the anhydricity of volcanic emanations; the lowered dew-point is the result of dilution of the air with anhydrous gases carrying hygroscopic solids in suspension.

One last observation regarding the great white cloud of Kilauea may be recorded alike on account of its beauty and its quaintness. A photograph is published showing the author's shadow thrown by strong sunlight on to the cloud, and he assures us that, when he took this photograph, there was no encircling halo round the image of

his head. Obviously, then, Brun is not yet numbered among the Saints of Science, and equally obviously the cloud did not consist of drops of water!

Brun now summarizes his results regarding the part played by water in volcanic action, and states them as *Laws*.

To quote these laws would involve too much repetition, but we may note his observations regarding the *volatile constituents of dead rocks*. These latter, heated *in vacuo*, frequently yield large quantities of water accompanied by oxides of carbon, free hydrogen, and subordinate nitrogen. The dead rocks differ from the active rocks both in the abundance of water and hydrogen which they liberate, and also, apparently, in their failure to produce volatile chlorine compounds ($NaCl$, KCl, NH_4Cl, HCl, etc.) and free chlorine.

We now come to the general *conclusions*, and a sketch is given of the manner in which in nature the emanation is often separated into various fractions, owing sometimes to condensation and sometimes to solution. At a late stage in the history of a volcano secondary emanations resulting from slow oxidation may still be important.

The primary exhalation is not necessarily violent, eruptive, and tumultuous, as one might imagine from hearing so much about paroxyms; an obsidian can crystallize, with concomitant emission of volatile constituents, very slowly and tranquilly, if only it be maintained at a suitable temperature for a sufficient length of time. Take, for instance, Lipari obsidian with 75·4 per cent. silica and an explosion temperature of 830°–902° C. It crystallizes at 523°–530° C. in radiating spherulites which gradually transform the whole mass. It is even possible to follow the change with the microscope. Carbon is expelled and localized between the spherulites; gas is given off; salts, which in the colloid were masked and insoluble in water, now concentrate and become soluble. All the substances are rejected through the crystallization of the silicates; but though rejected with the rest the salts probably play an essential rôle, as catalytic agents, in bringing about the crystallization. In support of this contention Brun points out that he has found no difficulty in obtaining *quartz* by heating amorphous silica with anhydrous chlorides.

And now the dethronement of water seems well nigh complete, but the *micas of the granites* still remain; they remind Brun of the old regime, and accordingly their heads are in danger; he remarks that the crystallization of granite must occur at a temperature very close to the destruction temperature of the micas, and adds that probably the formation of these micas takes place *a posteriori* through hydration. If by *a posteriori* he means to infer that the micas of granites are secondary in the ordinary sense of the term, then, with a vengeance, this is new wine for the new bottles, and of a brand that will find little favour with sober scientists. But if, as is more probable, he merely suggests a hydration of the magma from outside sources during crystallization, he has evidently raised a debatable point. It does not, however, seem obvious that outside help is necessary to account for the presence of the micas, or even of the water so often recorded from cavities in granitic quartz. According to Brun himself the volcanic exhalation contains abundant hydrogen (as NH_3, HCl, etc.) and

abundant oxygen (as CO_2, SO_2, etc.). All that seems necessary, therefore, is to suppose that, when sufficient pressure is brought to bear upon them, these two elements no longer shun one another but enter into compounds in association. There is much in this suggestion which would fall into line with a criticism offered by Gautier in 1907, and, as bearing indirectly upon the same question, one cannot forget the interesting results obtained by Barus regarding "Hot Water and Soft Glass in their Thermodynamic Relations" (*Amer. Jour. Sci.*, 1900, p. 161). Perhaps Brun may be persuaded some day to extend his experimental researches into this untrodden field. But all this, and much more besides, merely arises out of the book, it is not the book itself. The point which has been established, so far as can be judged at this distance from the seat of inquiry, is the anhydricity of volcanic exhalations. With the conviction of the truth of his discovery full upon him, it is not surprising to find Brun quoting Scrope's words written in 1825—

> "I conceive that no more effectual service can be rendered to science than the destruction of any one of those glaring errors which, apparently based upon a few specious facts, and backed by the authority of some great name, are received by the world in general without examination, notwithstanding that they contradict the ordinary march of nature, and consequently throw the extremest perplexity into that of science."

Those interested in volcanoes should consult the book for themselves. It is to be devoutly hoped that before long its results will be critically tested in the field. Considering the peculiar facilities offered by Kilauea it is perhaps not too much to expect that American scientists will soon take up the challenge and decide the issue once and for all.

E. B. Bailey.

II.—The Building of the British Isles, being a History of the Construction and Geographical Evolution of the British Isles. By A. J. Jukes-Browne, B.A., F.R.S., F.G.S. Third edition, rewritten and enlarged. pp. xv + 470, 80 maps and figures, London: E. Stanford, 1911. Price 12*s*.

During the eighteen years that have elapsed since the publication of the second edition of Mr. Jukes-Browne's *Building of the British Isles*, the records of their construction have increased so greatly that the author has found it necessary to rewrite the whole work. New material accumulates so rapidly that even since the publication of this edition further important changes have become necessary. Thus in the account of the Archean rocks Mr. Jukes-Browne holds that "there is little doubt" that the Moine Gneiss is in part altered Torridon Sandstone; whereas, to quote one opinion on the other side, the recent memoir on Glenelg shows that this conclusion is not accepted by the Geological Survey of Scotland. Mr. Jukes-Browne has made a most thorough study of the English literature, and he interprets it with stimulating originality, independence of judgment, and admirable fairness; thus, where the evidence tells against his former conclusions he candidly admits the fact (e.g., p. 341).

The feature of the book which first strikes attention is the

increased weight now attached to the evidence of the petrology of the sedimentary rocks. The importance of palæontology in the interpretation of physical geology has relatively declined. The stratigraphical correlation, on which the whole discussion rests, is no doubt ultimately dependent on the evidence of the fossils; but the lithological evidence is recognized as of increasing value and reliability. It is therefore natural to find that Mr. Jukes-Browne makes frequent reference to the luminous suggestions of the late J. G. Goodchild, a pioneer in this field of inquiry. A large share of space is given to such formations as the Trias, regarding which the lithological evidence is the most instructive. Mr. Jukes-Browne accepts the general conclusions as to the origin of the English Trias of Professor Bonney, who, he remarks (p. 233), "has given so much time and attention to a study of the Bunter deposits, and has such an intimate knowledge of the rocks concerned in the question, that no one is more likely to have arrived at correct conclusions on the subject."

The book consists of a brief introduction on general principles and of fifteen chapters, most of which deal with one geological period each. These chapters usually consist of a concise statement of the stratigraphical evidence, and a discussion of its indications as to the physical geography of each period. The results are illustrated by a sketch-map and sections.

It is impossible to refer to all the interesting, novel, and controversial questions with which the book deals, for it ranges from the genesis of Archæan gneisses to that of Boulder-clay; it considers how far the distribution of living Radiolaria gives reliable guidance of bathymetric conditions in Palæozoic times, and it has to deal with scraps of tectonic evidence which are capable of alternative or perhaps of several explanations. The sections on the Scottish pre-Cambrian and Cambrian rocks are the least satisfactory in the book; the chapter on the former shows the increasing weight attached to the formation of gneisses by absorption rather than by pressure alone. The author calls attention to the increase in the known range of the British Cambrians by their identification from bores in Suffolk; but the announcement of Mr. Campbell's discovery of Cambrian near Stonehaven, and the restoration of the Durness Limestones to the Ordovician, which involves a radical change in British Cambrian geography, came too late for insertion.

In the account of the Devonian System the author makes a useful protest against the too frequent description of coral-bearing limestones as coral reefs. He points out that some of the Devonian limestones thus described are crinoid limestones, and their identification as coral reefs can only be regarded as a mistake. He, however, appears to doubt whether any British Palæozoic limestones should be called coral reefs. From my recollections of some Devonian Stromatoporoid limestones, I have never hitherto hesitated to affirm the existence of coral reefs in English Devonian seas. The author quotes Goodchild's refusal to accept any of the coralliferous limestones in the Carboniferous beds to the south of the Lake District

as coral reefs. With a party of Glasgow geologists I visited one of the localities on the Solway last summer in consequence of a vigorous discussion on this question, and in comparison with various living coral reefs I felt bound to regard the limestones there as entitled to the name of fossil coral reefs. The question is no doubt largely a matter of definition, and Mr. Jukes-Browne's definition of a coral reef seems too exacting. The question is important, as Palæozoic reef-building corals like those of modern seas seem to have been limited to warm and shallow waters.

The chapter on the Old Red Sandstone gives a judicious summary of the various theories of its formation. Mr. Jukes-Browne now accepts the evidence of an actual land barrier along the Bristol Channel, which separated the Old Red Sandstone lake of South Wales from the Devonian Sea. He does not refer to recent arguments in favour of the marine origin of the Scottish Old Red Sandstone, and his most important proposals in this chapter are the reduction in number of the lakes proposed by Sir A. Geikie. It seems to the writer, however, that this is a step in the wrong direction, as the subdivision of the lakes is really required. The deposits are different from those of large lakes; and at least for some areas the most satisfactory explanation of the Old Red Sandstone seems to be that it was formed as widespread sheets of gravel and sand on the flood plains of shallow, inconstant rivers. These rivers would doubtless have widened here and there into lakes; and when they were cut off from the rivers and their waters evaporated, all their fish would have been deposited in a crowded fish bed. The abundance in some layers of pebbles with wind-worn shapes indicates the exposure of the shingle to sand erosion while lying on the stony flats.

The author maintains the view that the Chalk was deposited in a deeper sea than some recent authors have allowed it, and for at least some zones of the Chalk Mr. Jukes-Browne's conclusions seem most probable.

In his account of the glacial deposits the author calls attention to the fact that the word 'kame' is the Scottish for an esker. That question of nomenclature will have to be considered and settled. The term kame has been largely adopted abroad with quite a different meaning, so that the Scottish kames are not kames according to the foreign acceptance of the term. The greatest convenience of the greatest number would be secured by accepting kame for fluvio-glacial hummocks, although that course may be etymologically and historically incorrect.

The results of the author's study of the succession of English earth movements have a useful bearing on many questions of wide general interest. Thus he has recognized movements in the Midlands which have greatly affected the growth of our present river system. He dismisses Professor Davis' views, without much discussion, except on special points, as when upholding the greater influence of marine as compared with subaerial denudation in planing off the top of the Wealden anticline. Mr. Jukes-Browne recognizes that the rivers of South-Eastern England must once have arisen in the Welsh highlands.

as the uplift of the whole British area at the end of the Cretaceous doubtless formed a series of consequential rivers, which flowed across Britain from the western uplands to the North Sea. So far all British geologists agree with Professor Davis, whose paper discussing the relics of that primitive arrangement of our rivers must be regarded as a most important contribution to British geographical evolution. The chief difference of opinion is as to the date at which this system was destroyed. Mr. Jukes-Browne regards the Severn as a very ancient valley, whereas according to Professor Davis it is relatively modern. The plan of the existing rivers of Central and Southern England seems to result from a radial drainage from the Midlands. I called attention to some evidence in favour of this view in a paper on the Evolution of the Thames published in 1894; but that paper was incomplete, as it offered no explanation and cited no other evidence for the hypothetical central plateau, which the radial arrangement of the rivers seemed to indicate as having existed in Lower Cainozoic times. An area of highland might have been left there, owing to the more rapid subsidence of the land to the east and south; the Midlands might have been supported by the same ridge that had earlier caused the difference between the north-eastern and south-western types of the Lower Oolites. But for that supposition I knew of no direct evidence. Dr. Strahan and Mr. Jukes-Browne have now established an uplift of this area which would have served as the original feeding-ground of a radial system of rivers; these authors differ somewhat as to the date of the uplift, Dr. Strahan regarding it as Miocene and Mr. Jukes-Browne as Eocene. According to the latter view the Severn would be a very ancient river, and much older than the Thames.

In connexion with this question it is interesting to note the author's view regarding peneplanes, a spelling which he accepts as the more correct form of the word. He emphatically dissents from Professor Davis' view that peneplanes are due to subaerial action; he remarks that this "may be a theoretical possibility, but I think it has very seldom, if ever, been accomplished" (p. 425). That some peneplanes may be remnants of plains of marine denudation is quite probable; but it seems to be generally admitted that the formation of peneplanes by the combined action of river and wind is one of the most widespread of geographical processes.

In a book of so wide a scope and dealing with so scattered a literature there must be omissions and points where opinions differ. Thus, the statement (p. 454) that marine mollusca do not occur above the height of 500 feet in the Scottish glacial deposits shows that the author has overlooked Smith's excellent memoir on the Ayrshire drifts; the terms Bryozoa and Polyzoa are used indiscriminately (e.g. pp. 321–4). The author occasionally refers (as on p. 360) to dykes as lava-filled fissures, a practice which was once common among miners, but which they have fortunately learnt to avoid.

The author is conservative in the classification of some systems, such as the Silurian; and where he is less so it would have been useful if he had given some explanation or reference when he adopts a well-known term in a special sense, as in the use of Cenomanian for the Lower Chalk. Mr. Jukes-Browne is severe on the retention of

such names as Lower and Upper Greensand and Gault; he says no one can defend the retention of the first "awkward and inaccurate appellation" (p. 294). The use of names for series based on the typical localities is no doubt preferable for international correlation; but the old terms are of historic interest and they are often more easily remembered than terms based on unfamiliar place-names. Lower Greensand is no more misleading than Coralline Crag, Torridon Sandstone, New Red Sandstone, and other names which are retained.

Such points are, however, mere details, and one closes the book grateful to the author for this masterly summary of the former geography of the British area and confident that his work will stimulate fresh researches and serve as a platform upon which they can be safely based.

J. W. G.

III.—Le Genre *Caninia*. Par Achille Salée, D.Sc., Directeur de l'Institut Géologique de l'Université, Louvain. 4to; pp. 62, 9 plates. Bruxelles, 1910.

ONE is scarcely justified in saying that the pioneers of palæontology, when establishing their genera and species, reeked little of the morrow. The field was vast and there was much to do; yet they would surely be amazed to see how much labour has to be expended nowadays in order to verify their work.

A good example is seen in the monograph under notice, which is mainly concerned with the revision of two important species, *Caninia cylindrica* and *C. patula*. Most of the letterpress, and seven out of the nine quarto plates, are devoted to this object, and during the course of the work over five hundred sections have been made. It is a pleasure to find that the somewhat drastic revision of the genotype, which appeared in the pages of this Magazine[1] three years ago, is accepted in its entirety.

The value of the work is enhanced by the attention paid to the stratigraphical distribution of the material. An outline of Dr. Vaughan's zonal scheme appears in the Introduction, and the author throughout keeps in touch with the progress of zonal work in these Islands and in Belgium; discussing the scope of the monograph, he says that "il ne doit servir . . . que d'introduction à une étude detaillée de paléontologie stratigraphique sur le Calcaire carbonifère de la Belgique".

Caninia cylindrica was first described, from somewhat fragmentary material, by M'Coy in 1843 (*Siphonophyllia cylindrica*).[2] In the same year Michelin described a similar fossil as *Caninia gigantea*, his figured specimen coming from Tournai.

M. Salée has examined a cast of M'Coy's type, but apparently has not been able to procure topotypes to work on. Nevertheless he feels justified in identifying *Caninia cylindrica* amongst material from

[1] R. G. Carruthers, "Revision of some Carboniferous Corals": Geol. Mag., April, 1908, pp. 158–71, Pl. VI.

[2] His type is preserved in the Griffith Collection at Dublin, the locality being given as "Arenaceous limestone, Ardsallagh, Drumguin".

Tournai, which he has used as a basis for his revision. The accompanying plates are first-rate, the suite of five serial sections being very satisfactory. Sound reasons are given for regarding de Koninck's *Zaphrentis herculina* as a variety of M'Coy's species, as here understood.

Michelin's *Caninia patula* is revised from topotypes, and is treated very fully. On pls. vi–viii, there are five sets of serial sections, in one of which ten sections are figured (this specimen actually yielded forty sections). In addition two vertical sections are given, so that one obtains a very complete idea of M. Salée's conception of the species. In this case there can be no hesitation in accepting the revision. Michelin's type is preserved in the Musée d'Histoire Naturelle at Paris, where it had lain unrecognized for many years; in my experience, topotypes which are externally identical with this specimen give sections that agree entirely with M. Salée's figures and description.

Important additions are made to the synonymy of the three species, and two new varieties, *densa* and *vesicularis*, are associated with *Caninia patula* and *C. cornucopiæ* respectively.

The monograph closes with some remarks on the phylogeny of the genus, of which the ancestor is taken to be a *Zaphrentis* and the descendant a *Cyathophyllum*. Such an idea can only be regarded as tentative. It must be admitted that none of the species of *Caninia* can be shown to have descended from any Carboniferous species of *Zaphrentis* yet known. M. Salée justly considers that *Cyathophyllum* must be regarded as a polyphyletic genus, although it is very probable that it will eventually be possible to demonstrate that some of the Visean species were derived from *Caninia patula*.

The weak spot of the revision lies in the question of nomenclature between *Caninia cylindrica* and *C. gigantea*. If it can be said that Michelin's type is lost and that similar material from Tournai varies too much to be used as a basis for redescription, while topotypes of M'Coy's species are constant in character and agree with M. Salée's account of his Tournai material, then the revision can be accepted as a most satisfactory piece of work. But in the meantime the question remains an open one.

There are many interesting observations on ontogeny, and the mode of development of dissepiments is noted with care; some contribution is also made towards the solution of the very puzzling problem arising from the deposit of stereoplasma round the septa of many Palæozoic corals, especially in those of the *Caninia* group. The septa, which are of necessity bilamellar in all Anthozoa, are, however, erroneously considered to be unilamellar.

Typographical errors are chiefly apparent in the Bibliography.

These facts apart, the work is of much value. The lavish illustrations, mostly from serial sections, are especially useful in bringing out the specific constants in fossils of so variable a nature, and it is to be hoped that M. Salée will be enabled to continue his work on similar lines.

R. G. C.

IV.—British and Foreign Building Stones. A Descriptive Catalogue of the Specimens in the Sedgwick Museum, Cambridge. By John Watson. 8vo; pp. viii, 483. Cambridge: at the University Press, 1911. Price 3*s.* net.

THAT the practical applications of Science are receiving more and more attention at our Universities is a matter well known and of supreme importance. Nevertheless, the work before us comes to a certain extent as a surprise in showing what a very fine collection of building-stones has been gathered together from all parts of the world and arranged in the Sedgwick Museum. Great credit is thus due to Professor Hughes and those who are associated with him in teaching stratigraphical geology and petrology, as well as to Mr. John Watson, who has written the account of the specimens with evident care and after much painstaking research.

In his Introduction the author gives a general account of building-stones, with remarks on the value of different tests, on the qualities of stone adapted for various purposes, and in different regions and situations, on seasoning, and on the causes of decay. Then follow descriptions of the Igneous, Metamorphic, and Sedimentary rocks of all parts of the world, accounts of the quarries and the working of stone, historic and practical, with references to ancient monuments and to buildings of different ages where particular stones have been used. This portion of the work occupies about one-half of the volume, and it contains a large amount of interesting as well as useful information.

The remaining portion of the volume consists of the particular description of the rock-specimens, which number 1,126. They are arranged under (1) British, and (2) Colonial and Foreign, in each case under the headings of Igneous, Metamorphic, and Sedimentary. The following particulars are given so far as possible, but there are naturally many omissions, and the ages of Igneous rocks are not noted: Name (commercial or otherwise) of stone; Geological age (of Sedimentary rocks); Characters of rock-specimen, and if admitting of polish; Locality; Donor or Collector; Chemical composition; Weight per cubic foot; Specific gravity; Ratio of Absorption or Porosity; and Crushing strain.

The specimens are mostly 4½ inch cubes, with one face polished when suitable, one left rough, and the others dressed in the style generally adopted in the locality where the stone is worked.

It is to be noted that the petrological designations on the labels of the igneous rocks have been contributed by Mr. A. Harker, who has thus imparted a special value to this part of the book.

Roofing-slates, paving-stone, road-metal, and marble, examples of which are arranged in the Sedgwick Museum, do not come within the province of the work; but some flags and ornamental stones are naturally described under the building materials, such as Caithness Flagstone, Torquay Limestone, Hopton Wood Stone, and Larvikite (one of the Norwegian granites).

Although Mr. Watson remarks that the collection is "very far from being exhaustive", it is a capital representative series. No

British pre-Cambrian sedimentary rocks are included, but Torridon Sandstone might be added; and towards the other end of the geological scale there is a noteworthy omission of any reference to Greywether sandstone, while mention might have been made of Coralline Crag, which has yielded building-stone, and of British tufa, which, as at Dursley in Gloucestershire, has also been used for building purposes. It should be noted that the Bargate Stone (pp. 196, 317) is Lower (not Upper) Greensand; the "Bastard Freestone" of Shepton Mallet (p. 304) is Lower (not Upper) Lias; while on p. 165 Seaton should be Keinton Mandeville.

V.—The Movements of the Subsoil Water in Upper Egypt.

THIS subject is dealt with by Mr. H. T. Ferrar (Ministry of Finance, Egypt, Survey Department Paper No. 19, 1911). As he remarks, the effects of perennial irrigation in raising the level of the subsoil water, and its influence on health, and on crop-production, owing to the concentration near the surface of injurious salts, are matters of considerable importance. In studying the region the author finds it convenient to describe the wells and other hydrological subjects under the headings of *riverain*, *basin*, and *desert*: areas which form zones parallel to the Nile. Thus, "regarded broadly, the water-table in Upper Egypt behaves as a horizontal plane with flexible edges, which moves up and down as if actuated by an annual tide. The inner flexible edge, which is about one kilometre wide, is the riverain zone. This moves in the manner anticipated, namely, as a plane surface hinged along the side away from the river; but, instead of the hinged edge being on the desert edge, it rises and falls with the rise and fall of the water-plane beneath the basins. The basin zone, or horizontal part of the water-plane, moves up and down almost horizontally, and has an area not greatly less than the area of Upper Egypt which is cultivated. The outer flexible or desert edge of the water-plane, which we will call the desert zone, also moves up and down almost horizontally, but the range of its movement is considerably less than the range of movement of the basin zone."

The work, so far, has shown that consecutive observations extending over a number of years are necessary to complete the knowledge of the movement of the subsoil water. Experiments at present indicate that "In our so-called riverain zone, the water moves at the rate of 150 metres per day at one period of the year, and at other seasons, namely, when the water-table is stationary, it is practically stagnant. The water in the basin zone would seem to have a velocity of less than two metres per day, and that of the desert zone a still lower velocity". Furthermore, "Geological considerations have shown that the subsoil water mingles with the water of the Nile at all times of the year, and that interchange of Nile water and subsoil water takes place continually. In addition to the modifications introduced by geological structure, it has been found that artificial constructions have an influence upon the underflow, and that a quantity of water passes beneath and round the ends of barrages."

VI.—New Zealand Geology.

New Zealand Geological Survey.—In Bulletin No. 10 (New Series), 1910, Mr. Colin Fraser describes "The Geology of the Thames Subdivision, Hauraki, Auckland". The area forms part of the promontory of the North Island east of Auckland and south of Coromandel, and it includes Waihou on the south and Hastings on the north. The prevailing rocks of the area are Tertiary andesites and rhyolites, and they indicate three periods of volcanic activity, referred (with doubt) to Upper Eocene, Miocene, and Pliocene. These rocks form the hilly and mountainous ground of Hastings and the country east and south-east of Thames Town. The mountains, which form a part of the Cape Colville range, rise to elevations of 2,000 feet and more; indeed, Table Mountain, formed of a dyke of andesite, is reckoned to be about 2,800 feet above sea-level. The volcanic accumulations rest on an eroded floor of Jurassic and older sediments, which are exposed only in the northern portion of the area on and near the coast of the Firth of Thames. The pre-Jurassic strata have yielded no fossils, and the Manaia Hill Series, referred to Upper Jurassic, has yielded only *Inoceramus haasti* and *Belemnites*.

The southern portion of the area consists for the most part of the broad flood-plains of the Rivers Thames (or Waihou) and Piako, with raised sea-beaches and high-level river-terraces. Volcanic activity ceased about the close of the Pliocene period, and after the later earth-movements there has been much infilling of the bays by fluviatile agencies.

Special attention is directed to the Thames goldfield on the borders of Thames Town. There gold-silver quartz veins with ore-shoots are worked in the andesitic and dacitic rocks of the earliest Tertiary volcanic period. These quartz veins also penetrate the Jurassic and pre-Jurassic sediments, but this floor of older rocks is more than 1,000 feet below sea-level at the Thames goldfield. In the opinion of the author (pp. 3, 45) most of the ore-shoots "appear to show a considerable dependence on depth below the existing land-surface, since, irrespective of the elevations of the outcrops of the veins, the upper zone, extending to a depth of from 400 to 500 feet, has proved much the more productive . . . 500 feet has proved a critical depth on this field . . . The downward limit of the pay-ores mined appears, therefore, to conform roughly to surface-contours". He considers "that the principal veins at the Town of Thames occur in the near vicinity of the vent of an ancient volcano". Very little gold has been obtained from creek gravels, for, as the author remarks, while there has been much denudation of the ore-bearing veins, "most of this auriferous rock-waste was discharged by the streams on to an old foreshore now depressed hundreds of feet below sea-level, and overlain by recent alluvium."

Auriferous tellurides occur in a few localities. The author draws attention also to the widespread alteration of the volcanic rocks by hydrothermal action. The work is well illustrated with maps and sections, mining plans, and pictorial views.

VII.—Brief Notices.

Pre-Cambrian Rocks of Alberta, Canada.—Mr. C. D. Walcott has described a series of unaltered sedimentary strata, consisting of shales and sandstones grouped, as the Hector and Corral Creek Series, which lie unconformably beneath the Cambrian rocks in the Bow River Valley, Alberta. These pre-Cambrian rocks have not at present yielded any fossils. (Smithsonian Misc. Coll., liii, No. 7, 1910.)

Cambrian Fauna of North America.—Mr. Walcott calls attention to the "Abrupt Appearance of the Cambrian Fauna" (op. cit., lvii, No. 1, 1910). He remarks that "The evidence afforded by the few traces of pre-Cambrian fossils is inconclusive as far as determining whether their habitat was in marine, brackish, or fresh water"; but he adds that life was probably first developed in the open ocean, as advocated by Mr. W. K. Brooks, and that it became adapted to littoral and shore conditions in Algonkian time. The apparently abrupt appearance of the Lower Cambrian fauna is to be explained by the absence on the present American land areas of the sediments and organic remains belonging to the period between the formation of the Algonkian continents and the earliest encroachment of the Lower Cambrian sea. To this intermediate era Mr. Walcott applies the name Lipalian.

Iowa Geological Survey.—The Annual Report for 1909 (1910) of the State Geologist, Dr. Samuel Calvin,[1] is accompanied by reports on the geology of ten counties in Iowa by Messrs. M. F. Arey, T. H. Macbride, B. Shimek, and S. W. Stookey. The rocks described include Devonian, Carboniferous (Mississippian and Pennsylvanian), Pleistocene (Nebraskan, Aftonian, Kansan, Iowan, etc.), and Recent. The mammalian remains from the Aftonian Interglacial deposits include *Mylodon*, *Mastodon*, *Elephas*, *Equus*, etc.; those from the Alluvial deposits include Bison, Elk, etc. The origin of the loess is briefly discussed, and the view is supported that it is essentially æolian. Much valuable information is given on the economic branches of geology—on coal, building-stones, brick-clays, soils and forests, drainage and water-supply.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

1. *April* 26, 1911.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., Vice-President, in the Chair.

The President made the following announcement:—

"By the decease of Professor Thomas Rupert Jones, F.R.S., in his 92nd year, the Geological Society has lost one of its oldest and most valued members, who was formerly (1850–62) Assistant Secretary of the Society, and Editor of the Quarterly Journal. During his long life Professor Rupert Jones was an ardent geologist and palæontologist, and has left behind him in the Palæontographical Society's memoirs, in the Quarterly Journal of the Geological Society, in the Geological Magazine, and in the Annals of Natural History, no mean record of his abilities and strenuous labours. Nor was his work confined to original papers, but as Editor of the Quarterly

[1] Since this notice was written we regret to learn of the death of Dr. Calvin.

Journal of the Geological Society, the GEOLOGICAL MAGAZINE, the *Reliquiæ Aquitanicæ*, Dixon's *Geology of Sussex*, the *Arctic Manual*, and other works, he showed a high-class capacity in literature.

"Never in receipt of more than a very moderate income, derived from a small pension upon his retirement from the post of Professor of Geology in the Royal Military College, Sandhurst, he was unable to make any suitable provision for his death (when his pension ceased), and has left a widow with two daughters and an invalid son, almost wholly unprovided for.

"It is proposed to form a Committee of Geologists to consider the means of providing some memorial in aid of the widow and daughters of the late Professor. Any Fellows present willing to assist in this object are requested to communicate with the Assistant Secretary."

The following communications were read:—

1. "The Llandovery and Associated Rocks of North-Eastern Montgomeryshire." By Arthur Wade, B.Sc., F.G.S.

The area dealt with in this paper is in the neighbourhood of Welshpool. It comprises part of the Severn Valley and the whole of the Vale of Guilsfield. A summary of the work done is first given, and the deficiencies of the present geological map are pointed out.

The detailed sequence is as follows:—

SALOPIAN (1,000 feet)	Ludlow	Yr Allt Group	3. Sandy flags and shales, sometimes calcareous. 2. Hard thick flags, with thin shale-bands and septaria. 1. Thin muddy shales.
	Wenlock	B. Western facies	Blue flags, gritty, with calcareous concretions or boulders.
		A. Eastern facies	Blue flags, as a rule minutely false-bedded, with earthy mudstones, and a thin limestone bed.
VALENTIAN (700 feet)	Buttington Group (=Tarannon Shales)		Green and purple barren shales.
	Upper Llandovery	B. Western facies (Cloddiau Group)	2. Thick calcareous flags and mudstones. 1. Blue shales.
		A. Eastern facies (Cefn Group)	Thick calcareous flags, with *Pentamerus* Limestone.
	Lower Llandovery	Powis Castle Group	Red sandstone and conglomerate, with occasional limestone developments.
ASHGILLIAN (50 feet)	Gwern-y-Brain Beds		Black shivery shales, phosphatic with a band of black crystalline limestone near the base (=*Staurocephalus* Limestone?).
CARADOCIAN (1,300 feet)	Gaer-fawr Group		3. Calcareous mudstones and limestones (=Bala Limestone); coarse, ashy, felspathic bands. Thin, phosphatic, pale-grey shales at the base. 2. Massive grits, with bastard limestones. 1. Flags and grits, with some shale-bands.
	Pwll-y-Glo Group		Shales and flags, with some grit-bands.
GLENKILN-HARTFELL (=*Dicranograptus* Shales)	Trilobite Dingle Group		2. Nodular mudstones and grey shales, with *Trinucleus*. 1. Splintery grey shales, with *Diplograptus* (*Mesograptus*) *foliaceus*, etc.

In the detailed succession now worked out, the Ashgillian and the Valentian are for the first time distinguished, while the distinction between the Wenlock and the Ludlow Beds is brought out by means of graptolite zones.

The stratigraphical succession is shown by traverses; but, owing to successive overlap of the upper beds, no single traverse gives the full succession. The different groups are traced over the area mapped, and the chief fossiliferous exposures described, with full lists of the fossils obtained. The district is shown to be transitional in character between neighbouring districts on almost every side, combining many of their features.

The structure of the area is mainly that of an anticline with 'keystone' faulting, the dominant features being determined by the intrusive masses of the Breidden Hills and the small Standard Dyke of Welshpool. The two boundary faults of the arch have very considerable downthrows.

A brief account is given of the Welshpool Dyke, with chemical analyses of the rocks.

The glacial geology of the area is also described, three series of deposits being observed: (1) a high-level series, (2) a low-level series, and (3) a stratified series. The Guilsfield Valley is shown to have been occupied by a glacial lake, and the reversed drainage of the Cefn-Yspn Brook is shown to be connected with a 'col' through which the overflow water drained.

A short description of some of the fossils, including one or two new species, is given, and the paper is supplemented by correlation tables and maps.

2. Dr. J. D. Falconer, M.A., F.G.S., then gave an account of the Geology of Northern Nigeria, illustrating his remarks by means of lantern-slides. He pointed out that the Protectorate of Northern Nigeria covers an area of about 255,000 square miles, over half of which crystalline rocks are exposed at the surface. A series of hard banded gneisses of an Archæan type is intermingled with a series of quartzites, phyllites, schists, and gneisses of sedimentary origin, in such a way as to suggest that the two series, while originally unconformable, have been at a later period affected by a common folding and foliation along axes which are predominantly meridional in direction. The two series have also been pierced by numerous igneous intrusions of a granitic type, which are subdivided into (1) an older, wholly or partly foliated group, and (2) a younger, non-foliated group, characterized by the predominance of soda-bearing types.

Folded and faulted rocks of Cretaceous age are found in the valleys of the Benue and the Gongola. They consist of a lower series of sandstones and grits, in places salt-bearing, and an upper series of limestones and shales with numerous fossils of Turonian age. These Cretaceous rocks are overlain unconformably by a horizontal series of sandstones, grits, conglomerates, and ironstones, which in Sokoto province contains intercalations of Middle Eocene limestones. Considerable volcanic activity occurred during Tertiary times, and gave rise to extensive fields of basaltic lava in Bauchi and Bornu,

as also to numerous puys of trachyte, phonolite, olivine-basalt, and nepheline-basalt throughout Southern Bauchi, Muri, and Yola. Repeated minor oscillations of the crust occurred during the latter part of the Tertiary era, and culminated in the elevation of the Bauchi plateau, the depression of the Chad area, and the establishment of the present river-system.

2. *May* 10, 1911.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The following communications were read:—

1. "The Lower Carboniferous Succession in the North-West of England." By Professor E. J. Garwood, M.A., Sec.G.S.

The area dealt with includes the whole of Westmorland north and west of the Dent Fault, together with North Lancashire to the north of the Lune Valley, and the extreme northern corner of Yorkshire, to the west of Middleton in Teesdale, is also included.

The following general succession has been established:—

	Zones.	*Sub-zones.*	*Bands.*	*Probable Bristol Equivalents.*
Beds with *Lithostrotion*.	*Dibunophyllum.*	Upper (?)	Botany Beds.	D_3
		Middle: *Productus latissimus.*	*Saccammina.*	D_2
		Middle: *Lonsdalia floriformis.*	*Girvanella.*	
		Lower: *Cyathophyllum Murchisoni.*	*Cyrtina septosa.*	D_1
		Lower: *Cyathophyllum Murchisoni.*	*Davieslella llangollensis.*	
	Productus corrugato-hemisphericus. *Spiriferina laminosa.*	Upper: *Nematophyllum minus*	Bryozoa Bed.	S_2
		Upper: *Cyrtina carbonaria.*		
		Lower: Gastropod Beds.	*Clisiophyllum Keyserlingi.*	S_1
Beds without *Lithostrotion*.	*Michelinia megastoma.*	Upper: *Daviesiella carinata.*		
		Lower: *Camarophoria isorhyncha.*	*Spirifer* cf. *furcatus.*	C_2
			Thysanophyllum pseudo-vermiculare.	C_1
	Athyris glabristria.	Upper: *Seminula aregaria.*	*Rhynchonella triplicata.*	
			Productus globosus.	
		Lower: *Solenopora.*	*Eumetria proava.*	Z_2
			Pleurodictyum cleistoporoides.	
	Basement Conglomerate.			
	Spirifer pinskeyensis Beds.			

The value of the different zonal indices selected is discussed and their distribution over the area is described. It is shown that, whereas the zonal indices chosen for the larger groups of beds are often sporadically distributed in the zone, the bands form remarkably reliable horizons, extending frequently over large areas.

The rocks are described under the following districts:—

Shap and Ravenstonedale.
Kendal and Kirkby Lonsdale.
Arnside and Carnforth.
Grange and Furness District.
The Westmorland Pennines and Middleton in Teesdale.

For purposes of detailed description, the Shap–Ravenstonedale area is taken as the type, and the other districts are briefly compared with it. It is shown that in no one district is a complete development of all the zones observed, and that it is only by taking a broad survey of the whole area that the detailed faunal sequence can be definitely established.[1] In the Shap area the *Michelinia megastoma* Zone is scarcely represented, while farther west the fauna of this horizon is one of the richest in the whole of the North-Western Province.

The changes in the fauna of certain zones, when traced over large areas, often depend more on the lithological characters of the rocks and their modes of deposition than on the introduction of new forms at definite horizons; thus, certain corals, such as *Zaphrentis enniskilleni*, which is found to be associated with argillaceous deposits, characterize different horizons in different districts.

The deposits are shown to be for the most part of shallow-water origin. The period of great submergence appears to have been during the deposition of the *Nematophyllum minus* Beds and the Lower *Dibunophyllum* Beds.

The lowest deposits are characterized by highly magnesian limestones; these appear to have been deposited under lagoon-like conditions which encouraged the growth of calcareous algæ, especially *Solenopora*, and these in many places contribute largely to the formation of the deposits. The majority of the limestones throughout the series are rich in Foraminifera, and the more shaly layers in Ostracods and Bryozoa.

The silicification of the organisms at many horizons in the sequence is discussed, and the conclusion is arrived at that both silicification and dolomitization of the limestones were practically contemporaneous with the deposits in which they occur. The presence of spotted and 'brecciated' limestones is shown to be characteristic of the upper portion of the Lower *Dibunophyllum* Zone.

The movements which have affected the rocks in the Arnside district have been the result of nearly horizontal thrusts, and it is shown by means of zoning that the beds have, in places, been inverted and are dipping at over 120°.

[1] Thus the lowest zones are practically absent from the Cross Fell area, since the base of the Melmerby Scar Limestones represent an horizon high up in the *Nematophyllum* sub-zone: showing that the complete submergence of this district did not take place until long after that of the area farther to the west.

The palæontological divisions here described are correlated with their probable equivalents in the Bristol area; but no exact comparison has been found possible in the case of the lowest beds, which occur in Pinskey Gill.

In the palæontological portion of the paper several new species of Corals and one new genus are described, and the affinities of several Corals and Brachiopods are discussed.

2. "The Faunal and Lithological Sequence in the Carboniferous Limestone (Avonian) of Burrington Combe, Somerset." By Professor Sidney Hugh Reynolds, M.A., F.G.S., and Arthur Vaughan, M.A., D.Sc., F.G.S.

Lithology.—The series is almost continuously calcareous from the base of Z to D_1, where the section ends; the K beds are, to a large extent, shales. Crinoids are the prevalent limestone-builders throughout K, Z, and C_1; in C_1 the rock is largely of the coarsely crinoidal type known as 'petit granit' by the Belgian geologists.

A band of coarse oolite occurs in the upper part of K_1; but, apart from this, no oolite is met with until the top of C_1 is reached. C_2 and S_1 are very largely oolitic, conspicuous white oolite prevailing at the top of C_2. There is much oolite in the upper part of S_2.

An important point is the prominent part played by Foraminifera, which are the principal limestone-builders in C_2, S_1, and much of S_2. Many of the oolitic limestones are foraminiferal; but especially in C_2 there is much limestone abounding in Foraminifera, though not oolitic.

In the upper part of S_2 peculiar concretionary limestones, showing imperfect 'Cotham Marble' structure, occur; but these are not so prominent as in other parts of the South-Western Province.

The Burrington section agrees with the other sections in the South-Western Province, in showing dolomitization in the upper C_1 beds. A strong development of chert occurs at three levels—S_2, γ, and Z_1.

Palæontology.—The palæontological portion includes notes on several early mutations of well-known Carboniferous gentes, and deals, in detail, with the megastomatid Michelinias and the large Caninias (*C. patula* and *C. cylindrica*). The essential similarity of developmental stages in vesicular structures in widely distinct groups of corals is illustrated in the cases of *Caninia cylindrica* and *Lonsdalia floriformis*.

The early Syringothyroid stage in the Carboniferous 'Spiriferinas', a stage not observable in the Liassic type-species, is described, and the generic designation of *Syringothyris laminosa* is discussed.

A section is devoted to a comparison of the deposits at Burrington Combe with those at other points of the Belgian and South-Western Provinces. The great variability of deposit during the Mid-Avonian period is emphasized, and the rapidity of accumulation of beds of crinoidal debris is compared with the slow growth of dolomitic limestone at that time.

3. *May* 24, 1911.—Professor W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The following communication was read :—

"On the Geology of Antigua and other West Indian Islands, with reference to the Physical History of the Caribean Region." By R. J. Lechmere Guppy. (Communicated by Professor E. J. Garwood, M.A., Sec.G.S.)

After noticing the work of former observers on the geology of Antigua, the author gives a brief description of the formations of that island, showing that it is divided into three principal regions—(1) the Volcanic (or Igneous) Region; (2) the Central Plain; and (3) the Calcareous Formation; the first-named being, according to previous authors, the oldest, as it is pre-Tertiary, and the others following in succession. The Calcareous Formation, hitherto considered the newest, contains fossils, of which the most remarkable is a species of *Orbitoides*. After a discussion of these formations, and especially of the evidence for the so-called 'Oligocene' age of the Calcareous Formation, the conclusion is reached that this formation is the oldest, not the youngest, and is probably Eocene or older. The island was raised above sea-level by the development of the great Antillian dislocation, which is described, and divides each of the islands of Guadeloupe and Antigua into two parts, of which the eastern is calcareous and the western volcanic. In Antigua the Central Plain intervenes between the two parts, while in Guadeloupe they are only separated by a narrow channel. In support of this proposition the physical features of Antigua are discussed, and it is shown that the island has not been submerged since the volcanic period.

The position and age of the Scotland Series of Barbados are then discussed, and that series is shown to be Eocene, the lower beds being possibly Cretaceous and being a remnant of the Atlantis Continent.

The extension, age, and position of the *Orbitoides* Bed of Trinidad are next dealt with, and some further remarks are added on the physical history of the Caribean Region.

II.—Zoological Society of London.

May 23, 1911.—Dr. A. Smith Woodward, F.R.S., Vice-President, in the Chair.

1. A paper entitled "Tooth-Germs in the Wallaby (*Macropus billardieri*)" was presented by Dr. A. Hopewell Smith, M.R.C.S., L.R.C.P., and Dr. H. W. Marett Tims, M.A., F.Z.S., F.L.S.

The material upon which their observations were based had been kindly sent to the authors by Mr. Brooke Nicholls, of Melbourne. It consisted of three embryos of *Macropus billardieri*. The smallest specimen (allowing for the difference in size of the adults of different species) was considerably younger than that of any other Diprotodont previously examined. In the upper jaw they had identified six incisors, thus confirming M. F. Woodward's original statement. The functional incisors of the adult appeared to be the second, fourth, and sixth of the series. There were four premolars, of which the first, third, and fourth persisted. There was also one molar tooth.

In the lower jaw, owing to the difficulty of interpreting the conditions, it was not certain whether there were representatives of five or six teeth in front of the premolars. Presuming there were five, the large functional incisor of the adult was the fourth of the series. As in the upper jaw, there were four premolars and one molar, the second premolar not fully developing. There were evidences of vestigial predecessors to the large lower incisor and to pm. 4.

The following points of histological interest were noted:—

(1) The heaping up of the epithelium along the alveolar margins, a character often supposed to be peculiar to the Ungulates.
(2) The precocious development of the enamel.
(3) The compactness of the stellate reticulum of the enamel-organ.
(4) The abundant evidence of blood-vessels within the enamel-organ, thus confirming the observations of Poulton and Howes in the Rodents. The opposite opinion is usually held.
(5) Some slight evidence in support of the fusion of enamel-organs. Such fusion has been recorded in the fishes and reptiles, but not hitherto in mammals.

2. Professor J. P. Hill, D.Sc., communicated a paper by Dr. R. Broom, C.M.Z.S., "On the Structure of the Skull in Cynodont Reptiles." The author, after a study of all the available material contained in the British and South African Museums, gave a detailed comparative account, illustrated by a series of figures, of the morphology of the skull in the chief genera of the Cynodontia, including *Bauria*, *Nythosaurus*, *Cynognathus*, *Trirachodon*, *Gomphognathus*, *Diademodon*, *Sesamodon*, and *Melinodon*. He also discussed in some detail certain peculiarities of the Mammalian skull, apparently derived from a Cynodont ancestor.

3. Dr. C. W. Andrews, F.R.S., F.Z.S., read a paper "On a New Species of *Dinotherium* from British East Africa". The specimens described were sent to the British Museum by Mr. C. W. Hobley, Commissioner of Mines for British East Africa. They included portions of the mandible with teeth, a calcaneum, and a patella of a small species of *Dinotherium* nearly allied to *D. cuvieri*, from the Lower and perhaps Middle Miocene beds of France. The new species, which he proposed to call *Dinotherium hobleyi*, differed from *D. cuvieri* in several particulars—e.g., the inner anterior column of pm. 3 was more distinctly developed, and the talon of m_3 had a distinct tubercle on its inner side. Remains of Rhinoceros, a giant Tortoise, *Trionyx*, and Crocodiles also occurred. The bones were well preserved in a tough clay, and further collecting would no doubt yield important results.

CORRESPONDENCE.

LAND-ICE HYPOTHESIS.

SIR,—In the May number of the GEOLOGICAL MAGAZINE, p. 238, the Rev. Osmond Fisher calls attention to the evidence he has seen of disturbances in the rocks below boulder-clays, and suggests that the

subject is one worth investigation. With this view most geologists will agree. Such disturbances not only affect the rocks upon which the boulder-clays rest, but are to be found in all kinds of glacial deposits as well. Roughly speaking they may be classified as follows:—

1. Disturbances caused by tree roots.
2. The creep of the soil down slopes.
3. Vertical arrangement of pebbles near surface of ground.
4. Creep of soil-cap caused by masses of consolidated snow on slopes.
5. Dragging along of all kinds of deposits by glaciers moving over them.
6. Ploughing up of deposits by the snouts of glaciers or by stranded icebergs.

Granting that the contortions so frequently seen may have been formed in the several ways enumerated above would it not be a great step in advance if means could be found whereby the different kinds could be distinguished?

1. Roots of any size seldom penetrate very deep, but they spread out from the tree trunks near the surface for great distances in many cases. Their effect is not to contort the surface beds, but rather to destroy all traces of bedding at or near the surface.

2. Soil creep may be the cause of crumpling the surface layers of the softer rocks. Such movements would form disturbances which may be likened to waves, the crests and hollows of which would have a trend at right angles to the slope of the surface of the ground. The growth of vegetation would tend to prevent such creep, whereas the presence of much snow and frost would tend to make it more marked.

In the case of the binding of the harder sandstones and shales at the surface the only agent competent to produce the effect is either névé or glacier ice.

3. Dr. Strahan has called attention to the remarkable manner in which all kinds of objects on the surface tend to assume a vertical position in Spitzbergen. I have noticed that in the case of a large number of gravels which there is reason to suppose are of Interglacial age, the pebbles near the surface stand on end. It would be interesting to know if the peculiarity to which Dr. Strahan refers is something more than skin deep.

4. In the case of valleys containing snow banks on their sheltered sides, the creep might be of the same nature as 'soil creep' but more pronounced in character.

5. In many of our river valleys there are river gravels which show signs of great disturbance. Such disturbances are never found in the more low-lying deposits. Those disturbances are very marked on large flat areas and could not possibly be the result of 'soil creep'. They consist of plots and undulations the trend of which generally points to motion down the valley and not down the slope into the valley. Very frequently they extend to depths of from 8 to 10 feet, and I have seen them so marked that the gravel has been folded into the Keuper Marl and the marl into the gravel. To my mind the disturbances could not possibly be the result of soil creep or tree roots. Glacial conditions of short duration seem the most likely explanation.

Similar contortions may often be seen in glacial gravels and sands and beneath boulder-clays. Near Spendon, Derbyshire, a mass of Boulder-clay was contorted into the Keuper Marl and masses of marl were enclosed in the Boulder-clay; there were also striated boulders of Mountain Limestone deeply embedded in the red marl.

6. Many of the disturbances in the Chalky Clay seem to have been formed by the direct pressure of the ice front, others as at Cromer by the overriding of the Boulder-clay by the ice.

I agree with the Rev. O. Fisher that the subject is worth investigation, and feel sure that the question of how the disturbances and folds were produced can be ascertained by studying the details of the phenomena. One generally finds the subject dismissed with the remark 'surface creep'.

R. M. Deeley.

Inglewood, Lingcroft Avenue,
Harpenden.
May 23, 1911.

GEOLOGY OF PADSTOW AND CAMELFORD.

Sir,—Referring to the letter signed "Reviewer" which appeared in the April number of the Geological Magazine concerning the memoir on the Geology of Padstow and Camelford, I should be obliged if you would allow me to say that I entirely agree with the statements contained therein as to Mr. Ussher's priority in representing on a map the three main divisions of the Devonian Rocks in the area in question, and also to express my regret that no reference was made to this fact in the memoir.

J. J. H. Teall.

Geological Survey Office,
28 Jermyn Street, S.W.
May 26, 1911.

DREIKANTER.

Sir,—With reference to the discussion in your columns on the use of the word Dreikante, I should like to point out, as I have already done elsewhere, that the term is more appropriately employed for the comparatively common form with three long, nearly parallel edges, than for the rarer type which is roughly tetrahedral and has typically six instead of three edges.

If a stone lies on a sandy tract, the wind may, by means of the sand that it carries with it, bevel the upper portion of the side turned towards it, and at the same time gradually remove the sand beneath till the stone falls, turning over towards the wind on to its abraded surface. A new plane of abrasion will then be formed on the stone, making an angle of about 60° (a crystallographer would call it 120°) with the first, and, under favourable circumstances, by the repetition of the same movement a trigonal prismatic form with three parallel sides and edges will be more and more distinctly developed.

The tetrahedral or 'tripyramidal' form and other more irregular shapes would appear to be due to the stone falling over obliquely

instead of directly towards the wind, either on account of its shape or because the sand has been removed unevenly from below it.

If a general expression be required for any wind-shaped stone, we might speak of a 'ventifact', on the analogy of artifact, sometimes spelt 'artefact', which is already in use for an object, such as a palæolith, fashioned by men, and of 'ventiduct', which has been employed in architecture.

JOHN W. EVANS.

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June 7, 1911.

BRITISH PILLOW-LAVAS.

SIR,—The brilliant paper on British pillow-lavas by Messrs. Dewey and Flett in your May and June numbers is an illustration of what may now be done in rational petrology by the collation and interpretation of the great mass of facts accumulated on the descriptive side of the science. The main points brought forward by them, i.e. the existence of the spilitic suite, and the explanation of its association with black shales, limestones, and radiolarian cherts, seem now to be thoroughly established.

One is obliged, however, to dissent from the view (pp. 242, 245) that the spilitic suite is separate and distinct from, and, so to speak, co-ordinate with the Atlantic and Pacific kindreds, as established by Harker, Becke, and Prior. Using these terms merely as convenient names for the two broad chemical divisions in igneous rocks, and disregarding the much-disputed distributional assumptions on which they rest, it seems to me that the Atlantic and Pacific branches cover the entire field of igneous rocks. This is certainly the view taken by Harker in his *Natural History of Igneous Rocks* (chap. iv), although the terms Atlantic and Pacific themselves are based largely on the distribution of Tertiary igneous rocks. The actual basis of the classification, however, is chemical, and the above terms are due to a probably too wide generalization as to the distribution of the groups. If this is the case the spilitic suite is merely a subdivision of the Atlantic branch, as its characters agree well enough with the definition of the latter (Harker, op. cit., pp. 90, 91).

Exceptions to that geographical distribution of igneous types implied by the use of the terms Atlantic and Pacific are now multiplying at such a rate that it may be necessary to drop those terms in their petrographic sense. In that event future research may show that the igneous rocks are divisible into more than two main classes, distinguished by broad chemical and mineralogical characters, and associated with various types of earth-movements. The spilitic suite may form one of these classes; but what I wish to point out is that as at present defined it seems merely to form a part of the Atlantic kindred, using that term in the sense that petrographers use it, to indicate the great division of 'alkalic' rocks. Messrs. Dewey and Flett consider that a close parallel exists between the spilitic suite and the analcite-bearing igneous rocks of the Scottish Carboniferous (p. 209). If so, there seems no reason why the latter, or indeed any well-marked group, should not be elevated to the rank assigned to the spilitic suite by the authors.